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The Cover: The *B-29* Superfortress at the left is dwarfed by the *XB-36*, world's largest land-based airplane, which has a wing spread of 230 feet, a fuselage length of 163 feet, and is powered by six Pratt and Whitney 3,000-horsepower engines.

Consolidated-Vultee photo

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Atomic Power, Its Birth and Its Human Meaning

A. H. COMPTON

Doctor Compton develops the thesis that "wars between great powers are a thing of the past," in considering the portent of man's control of atomic energy.

ON December 2, 1942, in a war laboratory at the University of Chicago, was accomplished the first daring demonstration of an atomic chain reaction, releasing atomic power in an amount limited only by the controlling hand of the operator. I was fortunate to be a witness of the historic event.

A year earlier, just before the Pearl Harbor episode, President Roosevelt had asked the American scientists to put all possible effort into finding whether an atomic bomb would be practically feasible and to develop plans whereby it might be made. The Germans had been working actively on this problem. The British and American experts were agreed both as to its theoretical possibility and as to its great military significance. It remained to see whether the necessary scientific and industrial problems could be solved in time to give results in this war, and before similar weapons were produced by the enemy.

During the year that had intervened, preliminary experiments had shown how a chain reactor should be built. Pure uranium metal had been obtained in tons, whereas a year before only a few grams were available. Methods had been developed for starting, controlling, and stopping the reaction, and for measuring its rate of production of power. For years it had been assumed generally that producing the first atomic chain reaction would be an extremely hazardous experiment, with a good chance of producing either an atomic explosion or developing ionizing rays of lethal intensity. Our experimenters were convinced that it could be done safely, and the pressure of time prevented setting it up in a remote location.

THE FIRST ATOMIC POWER

On the morning of December 2, a reviewing committee of eminent engineers came to the laboratory. They were to recommend to the War Department whether actual construction of atomic bombs should be undertaken. Two weeks earlier their provisional report had been negative. This was their last visit to the Chicago laboratory to see whether in their final report they could recommend proceeding with the project with the full resources of the nation.

The reviewing committee met me in the conference room. Enrico Fermi, the great Italian nuclear physicist, who was directing the construction of the experimental atomic reactor, had asked to be excused. After an hour or two of discussion, the telephone rang. It was word from the research team. "We are ready to try the critical experiment."

I took with me the youngest member of the reviewing

New University of Pittsburgh cyclotron designed for general research purposes is the third largest in the world. The technician is adjusting the mechanism to oscillate target for ion bombardment. In the duraluminum chamber shown between poles of 100-ton electromagnet, ions are whirled at the rate of 20,000 miles per second, crashing against the target and rendering it radioactive. Target is inserted in vacuum through decompression chamber, the circular brass tube at right of window giving on vacuum box

Essentially full text of the Steinmetz Memorial lecture delivered May 27, 1947, in the Memorial Chapel of Union College, Schenectady, N. Y.

A. H. Compton, winner of the 1927 Nobel prize for physics, is chancellor of Washington University, St. Louis, Mo. In 1941 he was appointed head of the Committee of the Academy of Arts and Sciences to evaluate the use of atomic energy. He was in charge of the fundamental physical studies of the chain reaction for the Office of Scientific Research and Development and was director of the Plutonium Research Project.

committee and walked over to the laboratory. We entered the balcony at one end of the room where a dozen scientists were watching the instruments tensely and handling the controls. Across the room was the large cubical pile of graphite and uranium blocks in which it was hoped the atomic chain reaction would develop. Inserted into openings in this pile of blocks were the control and safety rods. When inside the pile, these rods absorbed so many neutrons that the chain reaction could not start. Just beyond the reactor, standing on a platform overlooking the pile, was the "suicide squad," men armed with equipment to destroy the pile and thus stop the chain reaction if all went wrong. A hundred feet away, behind two concrete walls, was a third group of men who followed the experiments with remote instruments, and who could set off the electric mechanism for throwing in the safety rods in case the reaction became too violent.

After a few preliminary tests, Fermi gave the order to withdraw the control rod another foot. We all knew this was the real test. The Geiger counters registering the neutrons from the reactor began to click faster and faster, until their sound became a rattle. The galvanometer pointer, indicating the current in the ionization chambers, began to move, at first slowly, then faster and still faster. The reaction grew until there might be danger from the rays coming from the pile. "Throw in the safety rods," came the order. Immediately the pointer moved back toward zero. The rattle of the counters fell to a slow series of clicks. For the first time, atomic power had been released, controlled, and stopped. It was only half a watt—infinitesimal in comparison with the atomic power that in the State of Washington, for nearly three years now, has been heating the streams of water flowing into the Columbia River. But it showed that man had the boundless energy of atomic fission under his control.

The men in the suicide squad breathed an audible sigh of relief. Someone handed Fermi a bottle of Italian wine. A little cheer went up. My guest and I returned to the reviewing committee. He was pledged to secrecy, but the glow on his face told the story. His eyes had seen a miracle.

Nine months later the first atomic reactor designed for practical use started its work at Oak Ridge, Tenn. It was built to develop heat at the rate of 1,000 kw. First it made in quantities large enough to handle, plutonium, the precious element needed to make the weapons that would end the war. After another year the three great plutonium producing reactors in the State of Washington went into operation. By now some 10 or 12 atomic reactors have been put to work. They vary in size from those that can be placed conveniently on a laboratory table to those that require a building larger than this to house them. Atomic power now is working for man.

The occasion of this Steinmetz Memorial lecture has prompted me to tell this story of the first release of atomic power in some detail. Steinmetz was also an initiator of first events, in which the laboratory invention developed into work of great industrial significance. Such is the pattern that we may expect atomic energy also to follow. Back, however, of these inventions lie years of world-wide work in basic science.

INTERNATIONAL CONTRIBUTIONS

Permit me, as an example, to review briefly the scientific background of the atomic power. Perhaps never was the making of an important invention shared by so many persons distributed so widely over the world. The early work of Becquerel and of the Curies, done in Paris on the process of radioactivity, was the first that showed us the release of atomic energy in nature. That the atom has a nucleus in which the energy resides was first strongly advocated by Nagaoka, for many years the director of the Imperial Institute of Science and Technology at Tokyo. Rutherford's demonstration and study of this nucleus, using as tools the alpha particles from radium, were classic experiments of the English school that developed the subject so greatly. In the discovery of neutrons, destined to play so important a role, the suggestive work of Bothe in Germany and Joliot in France led quickly to Chadwick's definitive experiments in England. Fermi in Rome learned how these neutrons could be slowed down and made to react with the nucleuses of various atoms. Lawrence in California, with his cyclotron, produced the neutrons in abundance, and made many new artificial species of atoms. Hahn and Strassman, working in Nazi Germany, came upon the fission of uranium atoms when they captured neutrons. That this remarkable splitting of the atom is accompanied by the release of energy manyfold greater than occurs even in radioactivity was predicted by Lise Meitner, and observed almost simultaneously in Denmark and the United States. When to this was added the fact, noted at about the same time by Joliot in Paris and by Szilard and Zinn in the United States, that the fission of a uranium atom results in the emission of several neutrons, it became evident to physicists everywhere that an atomic chain reaction was possible. It only remained to find a way of assembling just the right materials to make the reaction occur.

Joliot and Fermi, among many others, immediately initiated work to see whether indeed the neutrons emitted by a source could be increased experimentally by passing them through matter. Large amounts of rare materials had to be produced to make the results conclusive. Joliot, Halban, and their collaborators working in France obtained encouraging results using uranium and heavy water. The Germans, seeing here something of potentially great military value, worked hard on the possibility of separating the active isotope, uranium-235, from its more abundant twin, uranium-238. They knew that with enough of this uranium

isotope a chain reaction easily could be brought about, either of the controlled type or of the explosive type characteristic of the atomic bomb. Finding that this solution of the problem would require an industrial effort prohibitively great for them, they turned to the solution suggested by the French of producing a chain reaction in uranium and heavy water. This investigation they carried far enough to convince themselves that the chain reaction could be established if enough uranium and heavy water were available, and that it would not be explosive. They did not know, however, that element number 94, plutonium, which thus could be produced, would be fissionable like uranium-235. Accordingly, they did not see in the controlled chain reaction a means of making an atomic bomb. Discouraged by the wrecking of their main heavy water plant, and no longer seeing any important military advantage to be gained in the war then in progress by studies of the chain reaction unknown to us in the United States, they stopped their intensive effort to release atomic energy.

AMERICA'S SHARE

In the meantime, the American physicists concentrated their major efforts on effecting a chain reaction using the ordinary materials available without carrying through the enormous task of isotope separation. Fermi, working first at Columbia University, experimented with uranium and graphite assemblies. The Chicago experimenters, starting with Volner and Wilson, followed a suggestion in Russian physicists in working with uranium and beryllium. When in 1940 Seaborg, Kennedy, and Wahl, with the aid of the California cyclotron, produced and separated the first plutonium, a new possibility for obtaining material for atomic explosives presented itself. Calculations made by the British, and independently though somewhat later by the Americans, indicated that the amount of such material as U-235 or plutonium required for making a bomb was less than previously supposed. This greatly increased the urgency of making the chain reaction work. The safety of the United Nations well might depend on overcoming the year's head start of the German experimenters.

The story I have told of December 2, 1942, was the climax of the first stage of this intensive effort. Fermi and many other physicists, chemists, and engineers were brought together at Chicago. Other laboratories and many industrial organizations shared the effort. Because of the greater abundance of the material, graphite was chosen, instead of beryllium or heavy water, as the matrix in which the uranium was to be embedded. Careful studies were made of the most favorable arrangement of the materials. New methods were developed and put into operation for producing the uranium and graphite in purest form.

Others have told the rest of the story. Wigner and his collaborators designed a powerful chain reactor for producing plutonium in quantity. The du Pont Company worked with the Chicago scientists as they built and used the plant in the far Northwest of the United States. Other scientists, headed by Lawrence, Urey, and Keith, working with the General Electric Company and other great industrial organizations, built plants in Tennessee that produced the needed uranium-235. Oppenheimer brought to a remote mountain in New Mexico the greatest group of international master scientists ever to work together.

People now ask, how men could make themselves create and use a weapon so devastatingly effective as the atomic bomb? These scientists were lovers of peace. They dreaded destroying human life. Their ardent hope was that the product of their work should be used for good. They had, however, to choose whether the power in their hands should be made available to stop the war, or whether more millions should be doomed to fight and die upon the field of battle.

It is easy now to say, as many in all countries have said, that it is unfortunate that the first use of atomic energy was evil. Yet not to have used this new-found power to stop short the most disastrous war of history would have been unpardonable. Humanity's greatest need was a decisive weapon. We who had atomic power in our hands would have been traitors to mankind if we had not built the weapons and used them with tempered blows. It is our hope and fervent prayer that never again will atomic weapons be used in war.

Now the dreadful chapter of war is over. We look to the future. Atomic power, in the $4^1/_2$ short years of its existence, has performed a great human service. If the calculations of the Army and Navy were correct, without the atomic bomb and the help of Russia the war with Japan would have continued for many months. Now Japan has been started back toward reconstruction along the path of freedom. Those who were fighting against her have most of their armies back home, and their industries are producing the things needed to live in peace. What is the next great task of this newborn atomic Herakles?

Only the most obvious of the future developments now can be foreseen. One is reminded of the fact that for the first 50 years after Faraday discovered electromagnetic induction, its most important industrial use was for making hand-operated magnetos with electrodes attached, with which to entertain friends in the parlor! After this first 50 years came the incandescent lamp, the dynamo, and the building of power lines. Now the world depends on the electrical industry that is based upon Faraday's discovery.

Let us first consider the military significance of atomic weapons. Five atomic bombs have been exploded. These tests have shown that they can be used under a variety of conditions with the same assurance as to their

effectiveness as any other well-tried weapon. Their destructiveness both on land and sea is very great. This destruction is limited, nevertheless, under ordinary conditions, to a few kilometers from the explosion. These five bombs were early models. If it should prove necessary, much more destructive types probably could be made. In order to see their significance, however we do not need to imagine any further development. By making those of the present design in large numbers, the destruction they might produce would devastate the cities of any nation. They would make useless every harbor.

ATOMIC BOMB INSURANCE

Our studies have convinced us that there is no way to protect a city against destruction by such bombs except to insure that they shall not be used. I personally see only two methods by which we can get such insurance. The first and most certain is by an agreement in which all parties have confidence that no bombs will be made. This is what the nations are trying to achieve in the discussions now going on in the councils of the United Nations. We earnestly hope that their efforts will be successful. It is not yet evident, however, that such an agreement can be reached. If it cannot, the world presumably will fall back on the second and much less attractive method.

The second method is for each power that relies on its own strength for defense to prepare itself with atomic bombs and with means of delivering them effectively on any possible enemy. To avoid the reproach of the world, no nation would start an atomic war except in case of extremity, nor can preparation with atomic weapons insure victory if war should develop. For waging a war to a successful conclusion will require much more than atomic bombs. Readiness with such bombs will cause any possible enemy to hesitate long before starting a war, as, whether it is victorious, or not it will be sure to suffer severe destruction. The reasons for starting the war accordingly will need to be more compelling than those which have brought about any of the wars that have occurred during the last century. This method of protection would have the high cost associated with all competitive armament, and would supply a basis for continued international suspicion. It is, however, I believe, the alternative that will be followed if our attempts to reach mutual agreement should fail. With all its difficulties of high costs and continued suspicions, this method also would have the effect of making unlikely the outbreak of war.

PERMANENT PEACE A LIKELIHOOD

Before many years have elapsed, the social forces that I shall describe later will create conditions in which wars between great nations will be almost impossible. Thus, we can hope for freedom from war for centuries to come.

You see from this that I am not, like my friend Harold Urey, numbered among the "frightened men." I believe that the odds favor considerably the view that major wars between great powers are already a thing of the past. For the present, however, atomic weapons form an important part of our insurance against the outbreak of a new war. I am confident that we have a good fighting chance of establishing a permanent peace.

FUEL POTENTIAL

So much for the negative aspects of atomic energy. Let us now view it as a constructive force. Foremost among the evident uses of atomic energy is that of supplying heat and power. Using ordinary uranium as their source of energy, the plutonium plants in the State of Washington now are heating the water of the Columbia River at a fuel cost not greatly exceeding that of coal. This plant was not planned for fuel efficiency. The heat is only a by-product of the production of plutonium. It would be surprising indeed, if similar plants could not be built for using uranium at a far lower fuel cost than that of a coal-burning boiler of standard design. We must remember, however, that the size of the reacting unit, including the shield that protects from the lethal radiators, cannot be less than perhaps 100 tons. Furthermore, these reactors must be cared for by experts. This means that atomic heating units should be confined for the present to large installations.

Think of a city, long accustomed to a pall of winter smoke, supplied with atomic heating units that would warm its major buildings and perhaps supply hot steam to the houses and apartments in densely populated areas. This would seem to be a possibility.

Closely similar would be the problem of producing electric power. The most straightforward procedure would be to use the atomic reactor to heat steam to a high temperature, and then to use this steam in a turbine in the conventional manner. Basing their calculations on this experience, engineers consider it feasible to develop atomic power plants that will be roughly equivalent in cost of operation to standard coal-burning plants, and considerably cheaper to operate in regions where coal is scarce.

If these estimates are correct, it is a matter of enormous importance. It will make possible the spreading of industry into regions far from any supply of fuel. Electric power can be made available in desert areas where water must be conserved. By adding this new source of heat and power to the existing supplies of coal, petroleum, and water power, vast new possibilities present themselves. New territories will be opened. New areas will be made available for growing population.

How soon will this come? My own estimate is that it will be hardly ten years, if political difficulties do not

intervene seriously, before in the United States those responsible for establishing new power installations will consider uranium, in some cases, as a serious competitor with coal. It may be a generation hence before the total uranium power production will compare in magnitude with that from coal.

RADIOACTIVITY AIDS RESEARCH

Of even greater human significance than atomic power may be the result from the scientific studies made possible by radioactive isotopes of ordinary chemical elements. Thus, for example, with the help of an atomic reactor a form of carbon can be made that is radioactive. This radioactive carbon can be made a part of an organic molecule or of a living organism. These molecules or organisms can be detected and their motion observed by help of instruments that measure ionization. Thus can be studied the progress of a disease spreading through the body or the structure of a complex molecule, or the adherence of lubricating oil to a metal surface. Many different chemical elements can be made radioactive. The new possibilities thus opened to science are large and are just beginning to be used.

The list of possible applications of atomic fission could be extended indefinitely. The physicist thinks of the possibilities associated with the remarkable phenomenon of the diffraction of neutrons by crystals. The chemist thinks of making a whole series of chemical elements of higher atomic weight than uranium. The engineer looks to the forming of new molecules by the effect of radiation.

Fifty years ago it was evident that X rays were useful for "seeing" through objects, such as the human body, which are opaque to ordinary light. It could not then be predicted that X rays would become a powerful weapon in the fight against cancer. No one could foretell that studies with X rays would reveal the electron and with this discovery give us eventually the radio and a host of electronic devices. Such unforeseen developments are the result of every great discovery. Similarly it would not be surprising if the most important consequences of the release of atomic energy will be in directions not as yet predictable.

MODERN FORCES TOWARD PEACE

The most significant implication of man's release of atomic energy to my mind, however, is the striking attention this development calls to certain trends in the growth of society. Three of these trends are worthy of special note. All of them work toward the establishment of peace.

1. Science and technology are making of society a group of specialists, whose strength and survival depend upon co-operation. This is the first trend, toward increased and more widespread coordination of effort.

2. The society based on science demands technical knowledge and increased familiarity with human relations. That is, we want specialized training and humanizing education. This is the second trend, toward more adequate education for larger numbers of people.

3. But above all, the society shaped by growing science requires formulation of adequate objectives. Only as these objectives are understood and accepted as worthy of concerted effort can cooperation be secured among free people. This is the third trend, which is most important of all in the growth of the human spirit. It is the search for a harmonious set of values, ideals, and objectives, which will bring order into our activities and meaning into our life.

These trends have been present since the dawn of modern science. The birth of the atomic age, however, gives them dramatic emphasis and stimulates their more rapid progress. Consider how they are illustrated by the atomic energy program.

We have reviewed briefly the many sources from which came the scientific background for releasing atomic power. Perhaps never has been achieved more extensive and complete co-operation among such widely varied groups as in the gigantic task of making the atomic bomb. Scientific specialists of a thousand types, engineers, managers, labor, skilled mechanics, construction crews, secretaries, Army and Navy, whites and negroes, Americans and Europeans, all worked with co-ordinated efforts. Many differences arose, but all were intent on completing the job. Differences were set aside in order to reach the common goal. The need for co-operation was evident, and this developed a desire to work in friendly spirit. Enormous strength resulted from such a team of co-ordinated specialists.

The reverse of this picture is that a major means of fighting an enemy is to disrupt the co-operation among his different groups. The great strength of a society of experts with special skills working together becomes tragic weakness when one group fails to do its part, or when barriers prevent various groups from working for each other. This means that war in a new sense is becoming a crime against humanity, for it stops the co-operation that is required to supply human needs, and thus causes widespread disaster. Conversely, as peoples become increasingly aware of the importance of the contributions to their own needs that come from other peoples in other lands, the demand to maintain and develop such co-operation will create a mighty positive force for peace.

WARS NO LONGER PROFITABLE

Thus a nation no longer can look to a war of conquest as a means of improvement of its economic position. From here on it becomes increasingly clear that a nation's economic advantage lies rather in promoting its own industrial development as a part of a worldwide growth in prosperity. In a world where strength and prosperity are closely allied to technical development, the welfare of each group depends increasingly on the growing welfare of other groups. It is in this sense that the concept of "one world" takes on a real

meaning. We are in an active stage of transition from small self-contained units toward a global society, all of which is interrelated closely. In the field of science this global unity is already an accomplished fact. With regard to commerce and industry, the increasing importance of world-wide exchanges are pressing world governments to relax the political barriers. Increasingly rapid technological advances are moving toward a situation in which world-wide co-ordination of effort will become a matter of prime economic importance. This is the dominant trend of society, the end of which can be nothing short of world-wide co-operation. When this co-operation is recognized as vital, there must come protection against placing in its way barriers such as would be caused by war.

World government that will keep in ordered relation the work of the many nations is the inevitable goal toward which the great forces of social evolution are rapidly moving. In this integrated world community, harmony of activities is necessary, and conflicts between groups must be resolved with minimum interference with others. Elimination of major international war appears thus a sure by-product of the continued growth of science.

THE TIMETABLE FOR GLOBAL CO-OPERATION

With regard to the time schedule of this growth toward a world community, one cannot be so sure. We have seen the rise of the League of Nations and of the United Nations. We have seen in a generation the substantial growth in economic and political importance of those governments that co-ordinate the life of peoples over large areas. More important even than these landmarks I should place those of technological and commercial developments that require very large scale organization to make them effective.

The development of atomic energy is typical of an increasing number of extensive undertakings engaging, even in their initial phases, the activities of a million persons spread over a large part of a continent. World-wide shipping and air transportation is another. World-wide radiobroadcasting chains are in process of formation, and demand international control, if not operation. The number of such technical developments with which the world is concerned is increasing rapidly. If another war does not intervene within 30 years, the pace of this advance is such that the advantages of keeping open the channels for international co-operation will have become increasingly evident. The probability of war then will diminish rapidly to a remote possibility.

If we want peace, we must encourage in every way possible the growth of those activities that promote human welfare through the co-ordination of effort throughout the world.

Of the second trend, that toward more technical and professional education the atomic program again is a typical example. It was not possible for the suggestion of releasing atomic energy to arise except in the minds of those scientists who were at the very forefront of their profession. In planning the experiments leading to the first chain reaction four years ago, only the best trained men could be of service. Co-ordinating the activities of science and industry and the military required men highly skilled in administrative problems. To carry through the difficult jobs required competent engineers and many thousands of skilled workmen. Similar skills must be available wherever progress along technological lines is to come.

Those who have been in contact with activities such as these have become acutely aware of the value of education. As a result, more people are wanting more education. This is the great phenomenon of the educational world.

The third trend, that of searching for adequate objectives, is related intimately both to growing co-operation and to increasing education. Again let me use the atomic program as an illustration. The world-wide scientific studies that led to the development were carried on by many investigators who saw value in the effort to understand the truths of nature. By comparing and sharing ideas and discoveries, each was able to advance toward the common goal of better understanding. With the advent of the war, fear of defeat and desire to bring the war to a prompt conclusion drove all concerned to submerge the individual difference in the interest of the common goal. Co-operation in the atomic project came not because of mutual affection, but because all were determined to do their best toward making the enterprise a success.

WORTH-WHILE PEACETIME GOALS

When peace comes the goals are not so evident. The war was waged to protect against disaster. The objectives of peace seem more diffuse. Yet what can be more vital than the desire of a man to grow to his full stature? If he recognizes the elementary law of human nature, that one's own full growth requires that he help his neighbors to grow, he thus finds a goal toward which all can work. This goal is nothing less than giving every person the best opportunity we can for full physical and spiritual development.

Such an objective implies a freedom from want which until now would have been considered a Utopian dream. With recent advances in technology and the strength of industrially organized society as demonstrated in the war, it is now evident that society can free itself from want if it is determined to do so.

But physical wants are only the beginning. We have lived a generation that has had more than the usual number of lost souls, who found nothing of value to which they could fasten their lives. The need is now felt to find such true values.

In these great social trends we see the growth of the human characteristics that we most highly cherish.

The spirit of co-operation is the love of one's neighbor as expressed in service. Increased education is the result of the love of knowing the truth. In devotion to worthy goals one finds that his own life takes on meaning and value.

Just after Hiroshima, Norman Cousins called our attention to the fact that "modern man is obsolete." Man who had performed technological miracles was not fitted for life in the Atomic Age. Why?

Modern man has concerned himself with working for his own interests. He has trusted God, or the state or social evolution to see to it that what worked for his own interest would promote the common welfare. The world in which we now find ourselves cannot survive under such actions. Things happen too fast. Our actions, as dramatically exemplified by the atomic bomb, affect too large a circle. No longer is there time or opportunity in our rapidly changing world for actions aimed toward self-interest automatically to build up the community's strength. If we are to be strong, if we are to prosper, if we are even to survive it can be only by consciously working for each other. This, which we have known as the law of the life of individuals, is now likewise the law of nations.

Such service for the common welfare is required by the fact the nations, like individuals, are now specialists, and can prosper or even survive only by co-operative effort. Schenectady must serve not only the nation, but the world. And as the world learns to depend on Schenectady, its prosperity becomes the world's concern. This is the sure path to peace.

There is an ancient legend of Daedalus, who learned the art of working steel. By long labor with forge and anvil he fashioned a sword which he gave to King Minos of Crete. His friends came to him and expostulated, "Why did you give the king a sword? That will not bring us happiness; it will bring us strife." Daedalus replied, "It is not my intention to make you happy. I would make you great."

If science is the steel of Daedalus, he has used it to fashion the atomic power, which four years ago today he gave to man. We dread the destruction it can produce. But we cannot give it back. We must use this power to enrich the life of man. For its use the world must learn to work together. We must fit ourselves with further education. We must select worthy goals that will harmonize the efforts of all. Thus man will become truly great. Let us thus choose to serve, and live.

National Office of Bibliography

In an address before a regional meeting of the American Institute of Chemical Engineers in Louisville, Ky., February 18, 1947, the essential substance of which appeared in *Chemical Engineering Progress*, June 1947, H. F. Willkie (Joseph E. Seagram and Sons, Inc.), decried the lack of co-ordinated research in the United States. To alleviate this condition, Mr. Willkie suggests that a post of secretary of research in the President's cabinet be set up. In summarizing the activities of a secretary of research, Mr. Willkie says:

"It should be the function of such a secretary to establish a national research foundation which would have *three* broad functions: first, correlation of research done currently through universities, private foundations, government agencies, and individual efforts; second, performance of original research, or delegation of that research to be performed, in fields not covered by independent agencies, and where the national interests seem to require the exploration of material not presently available; and third, dissemination of technical publications for universities and research workers, and simplified reading matter for the non-technical person, similar to the Department of Agriculture documents.

". . . He should direct the establishment of a national office of bibliography for the purpose of exploring all printed results of research in English and other languages, cataloguing material, translating and abstracting when necessary, and issuing an annual index of catalogues to all libraries, universities, museums, and industrial research laboratories.

"The scope of this project should be as broad as our culture. It should include all the arts, languages, sciences, history, medicine, industry, agriculture, and commerce. It should be designed to collect and disseminate materials which will give Americans a sense of perspective regarding their own cultural and economic history, their present status, and their destinies. While it would be of great service to all industrialists, administrators, university professors, researchers, and technical workers, it also should supply a vast amount of material which could be read and appreciated by millions of plain citizens, ordinary men and women who, at present, depend for their education upon inadequate schooling, biased journalism, sensational films, and superficial magazines. This important voting group now makes haphazard decisions, vital to national and international welfare, without regard or access to the scientific method of determination."

Discussing the possible political perversion of the materials of research, he says:

". . . Adequate organization would be a protection against perversion, and an added assurance would stem from the numerous independent institutions throughout the country and abroad, acting as inevitable checks and balances against misuse of such a concentration of research power.

"There is a strong sense of professional ethics among research workers; we cannot go wrong if we assume that the majority of them are primarily interested in the truth. Already certain beginnings have been made through public agencies. No one would claim that the United States Public Health Service, under the direction of the Surgeon General, has perverted or injured the science of medicine; that the Department of Agriculture has misled the farmers; or that the Library of Congress has falsified its record in the interest of politics. These are but samples of what could be done."

Modern Railway Passenger Car Auxiliary Power Equipment

D. R. MacLEOD
MEMBER AIEE

JACK HAUSE
ASSOCIATE AIEE

Immediately after the close of World War II, the railroads began to order a large number of passenger cars in an effort to retain part of the passenger business that had come to them during the war years. As might have been expected, a large number of different ideas were given a quick try-out and adopted by different railroads. Many of these ideas had as their basis a very large increase in the amount of power which would be required for electric devices on the cars.

RAILROADS today have approximately 3,000 cars on order. This tremendous building program was foreseen during the war, and insofar as was possible the engineers of the railroads and of the manufacturing companies planned for it. Air conditioning, fluorescent lighting, and electromechanical water coolers were specified for almost all the cars. Some railroads have given consideration to air-conditioning equipment of greater capacity, electrostatic air filters, bactericidal lamps for water facilities, 60-volt d-c fluorescent lighting, small refrigerators in roomettes, public address systems, radiobroadcast reception, movies, and even electric blankets.

In keeping with their policy providing the maximum degree of comfort and entertainment for their passengers, consistent with good economy, the railroads have been experimenting with the development of new types of dining cars. Electromechanical refrigeration, full-scale electric cooking, garbage disposal units, and electric dishwashing will add to the efficiency of dining cars and comfort of the kitchen crew.

All of these devices call for increased generator capacities on cars. One all-electric diner which now is being built will have a total maximum generating capacity of 66 kw. Conventional dining cars are being equipped with generators having maximum capacity of 50 kw. Coaches and sleeping cars are being equipped with generators having maximum capacities between 20 and 35 kw. Most of the cars being built today will be owned or controlled by the railroads in the East. Therefore, the great majority of new cars are being equipped with axle-driven generators. In the West where the railroads must contend with long grades, many have adopted engine-driven generators for lighting and engine-driven compressors for air conditioning. The majority of these have been of relatively low capacity in each unit and have used propane as the fuel. The trend appears to be toward the use of a single engine-driven unit for the supply of electromechanical air conditioning, fluorescent lighting, and all other power services on the cars. These engines probably will be of the Diesel type using standard Diesel fuel and probably will drive 3-phase 60-cycle alternators at 1,800 rpm. Even on these cars equipped with engine-driven alternators, batteries will be required for emergency lighting and for supplying power in terminals or other locations where the engines cannot be run.

GENERATOR DRIVES

Cars equipped with axle-driven generators have been equipped with batteries ranging from 1,200 ampere-hours at 32 volts to 600 ampere-hours for 64-volt and 114-volt d-c systems. A large number of these cars have been supplied with means for converting direct to alternating current for fluorescent lights, fan motors, and electric razor outlets. Most of the new axle generators are equipped with a-c motors which can be plugged in for the supply of power while the car is not in motion. These a-c motors are built for use on 220-volt 3-phase 60-cycle power, as this has been standardized very well by the railroads for use in their terminals. Many of the axle-driven generators are driven by a Spicer drive which consists of a gear unit mounted on the axle of the car, a propeller shaft, and a safety clutch. When a motor generator set is used for the axle generator, an automatic clutch is used in place of the simple safety clutch. It engages when the drive shaft from the axle of the car is rotating at approximately 280 rpm, thus permitting driving of the generator by means of the a-c motor mounted on the same shaft.

Since it appeared impossible for the railroads to standardize on any one voltage or system of power supply, it became necessary for the electrical manufacturers to design their equipment with the objectives of using the greatest number of parts common to all units of a given line to keep manufacturing costs and the number of renewal parts within reason.

Essential substance of paper 47-153, "Modern Railway Passenger Car Auxiliary Power Equipment," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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With the growth of load which accompanied the introduction of air conditioning, the heavy currents which had to be handled and the large cables required to transmit these heavy currents with low voltage drop caused a number of railroads to investigate the possibilities of higher voltage systems. One big drawback to higher voltage systems was the increased hazard of grounds due to leakage over battery terminals. Consideration also had to be given to continuity of service, so that in case of failure on one car, the circuits could be plugged through to an adjacent car.

BATTERIES

There are two types of batteries in general use on railway passenger cars. These are the lead-acid type battery and the nickel-iron-alkaline type. The characteristics of a battery on charge are affected by the temperature of the battery and its age. Some railroads using lead-acid batteries have applied temperature-responsive relays in the battery boxes to adjust the charging voltage in response to battery temperature assuring a more nearly correct amount of charge. Some railroads have adopted the device of lowering the charging voltages slightly when the charging current falls below a certain value. The temperature compensating relay accomplishes the same purpose and is a more correct indication of the charging voltage to use.

Other things being equal, a battery having high rates of charge and discharge will have a shorter life or require more maintenance than one having lower rates of charge and discharge. In the application of axle-driven generators, the objective should be to keep the rates of charge and discharge as low as possible. The criterion of ampere-hours into the battery and ampere-hours out of the battery is used to determine the correct application of axle-driven generators.

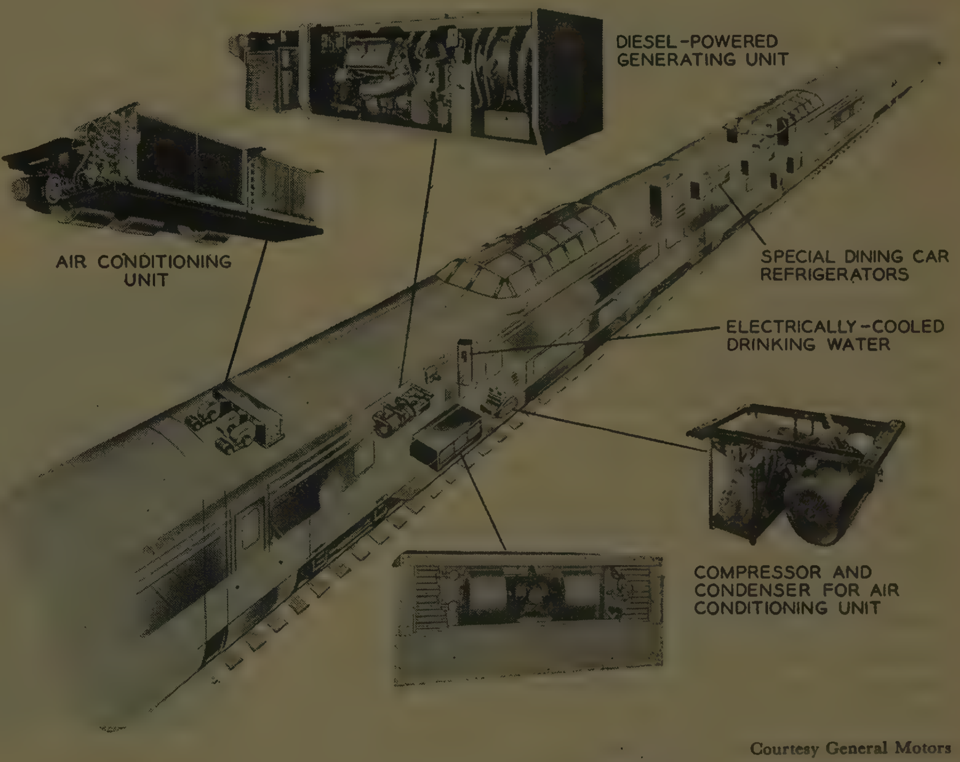
AXLE-DRIVEN GENERATOR

The function of the axle-driven generator is to supply the load while the train is moving at speeds above that at which the generator is capable of cutting in and to keep the battery charged, so that when the train speed falls below the cut-in speed, the battery will be able to carry the entire load on the car until the train can resume a higher speed or until it reaches a terminal. The axle-driven motor generator may be provided with a number of different gear ratios, so that the same generator operating within its permissible speed range may be used for high-speed or slow-speed trains. Prolonged drain on the battery requires a generator with a wide speed range. Considerable freedom of design exists within a given size of generator. Since most railroads have some margin above their maximum operating speed, the stability of the generator becomes of particular importance at speeds below approximately 90 per cent of maximum permissible speed. However, the regulator designer must take the maximum stability into account in designing his regulators to prevent hunting at the maximum permissible speed.

At the lower end of the speed range the designer is faced with the problem of field heating because the field amperes are a maximum at the cut-in speed. The full-load speed is the significant speed and is defined by the American Association of Railroads' specifications in the following manner:

The generator with covers arranged as in summer service shall be capable of delivering for three hours for enclosed and five hours for ventilated machines at the output side of the generator regulator at all speeds above 1.25 times minimum full load speed:

1. Rated current at rated voltage without exceeding specified temperature rises.
2. Rated current at all voltages up to 20 per cent above rated voltage without injurious heating.



Courtesy General Motors

Figure 1. Section of General Motors Train of Tomorrow illustrating electric power supply and auxiliaries

Figure 2. A-c–d-c motor generator set for use on railway passenger cars

The motor generator sets for 32-, 64-, and 114-volt d-c batteries, manufactured by one company, all have the same outline dimensions and approximately the same weight (Figure 2). They are 2-bearing machines for suspension by bonded-rubber resilient mountings beneath the car body. The machines are self-ventilated with fan mounted on the armature shaft. Baffle type air cleaning is provided in the air entrance passages at both a-c and d-c ends of the machine. Many of the parts are interchangeable on the different machines.

The control system for these motor generator sets consists of a voltage control relay panel, generator control panel, and a 3-pole across-the-line a-c motor starter.

This type motor generator has an armature reversing switch mounted on the commutator end of the set, and the initial revolution of the motor generator operates this armature-reversing switch to correct generator polarity for the direction of train travel. Terminal voltage of the generator builds up through self-excitation.

In applying these axle-driven motor generators sets for a particular run, it is necessary to consider not only the kilowatt rating but also the minimum full-load speed. The best generator for the job is the one that results in the least ampere-hour discharge from the battery.

A-C POWER SUPPLY

Railroads have long realized the advantages of induction motors for use on passenger cars instead of commutator motors. This advantage of a-c power has been brought more forcefully to their attention in recent years by innovations such as fluorescent lighting. The requirement for a-c power has led to many different methods of obtaining it.

An ideal system of power supply for the electric loads on railroad passenger cars consists of a large engine-driven generator power plant consisting of two or more units at the head end of a train. The operating disadvantages are principally those associated with an interchange of cars between different railroads and within different trains on the same railroad.

Most railroads require that any passenger car be capable of carrying its air-conditioning load for at least two hours independent of any outside power source. Even where a-c plug-in power is available in yards and terminals, there are other conditions which require a relatively large battery. These batteries must be charged at a relatively high rate, while the car is running, putting a heavy drag on the locomotive. On some railroads the variation in the number of cars that have to be hauled by the same locomotive in different trains may be so great that no credit can be given to a self-contained power plant for the saving in locomotive horsepower. But where trains of the same length are hauled by the same locomotives day after day, the saving in locomotive horsepower can be credited to the self-contained power plant. In this case an engine-driven power plant on each passenger car with a relatively small battery for starting the engine and for emergency incandescent lighting will be more economical than an axle-driven generator and large storage battery. The problem of noise, exhaust fumes, and maintenance must be evaluated, and these considerations may outweigh first cost advantages of the individual power plant.

DIESEL POWER PLANTS

In recent years, the Diesel fuel has become available on a number of railroads, and railroad shops have become proficient in maintaining this type of engine. The advantages of a-c power for motors and fluorescent lighting have turned the attention of several railroads to Diesel-engine-driven power plants that can be mounted under a car. Advances made during World War II in the design and building of reliable small engines and also advances made in the electrical field in design and construction of a-c generators and the voltage-control components have made this possible. Figure 3 shows a 25-kw 230-volt 3-phase 60-cycle power plant for undercar mounting. Much attention has been given to accessibility of the power unit for maintenance.

Figure 3. Diesel-engine-driven 25-kw alternator power unit for under car mounting with unit swung out 180 degrees for maintenance

There are several problems associated with the use of small engine-driven alternators on cars. First and foremost is the need for clean air for the engine intake. Since fluorescent lighting usually will be operated on the same bus as the air-conditioning compressor motors, the response of the engine governor and the speed of the voltage regulator must be given careful consideration.

Self-regulating motor alternators use static devices and auxiliary fields to control alternating voltage and frequency. Resistors that change their value with voltage are used to modify the field of the d-c motor in response to load, and a differential field excited by rectified a-c load current is used to compensate for changes in speed due to load. The d-c motor current is fed into the a-c field to compensate for impedance drop with load. Since the a-c amperes depend on the kilowatts of the load and its power factor, and the d-c motor amperes depend upon the kilowatt load and applied direct voltage, it can be seen that this system gives only approximate control of voltage and frequency under varying load conditions. It is used where a-c motors are not started from the same bus that supplies fluorescent lighting.

Vibrating-reed inverters are used where small a-c power outputs are required, as for razor outlets on Pullman cars and coaches that do not have other sources of alternating current. They have proved economical on applications where intermittent service is required. The modern type is designed for ease in replacing parts that are subject to wear.

The only practical method that has been developed of getting constant-voltage constant-frequency a-c power from the axle of a car is to generate d-c means of an axle-driven generator and then convert to alternating current. This double conversion means a serious loss in power and, therefore, it is important to use as efficient a conversion unit as possible. With existing air-conditioning systems the advantage of driving the air-conditioning compressor with an a-c motor has not justified the conversion of all the d-c to a-c power.

The nearest approach to the all a-c power car would be a car with a-c power for motors, fluorescent lighting, radio and public address systems, and electric razor outlets, except the air-conditioning compressor motor and emergency lighting. This a-c power can be supplied by one machine if that machine has voltage characteristics that will allow a 1-horsepower induction motor to be started on the same a-c power supply bus as the fluorescent lights. This has been done by supplying 5-kw 6.25-kva amplidyne-booster inverters. The principal electric loads on the car, except the 15-horsepower air-conditioning compressor motor which is fed directly from the d-c bus, are carried by the amplidyne-booster inverter.

The amplidyne-booster inverter supplies substantially constant 230-volt 3-phase 60-cycle power within the operating range of the axle-driven generator and storage battery. Equipment consists of an inverted converter in

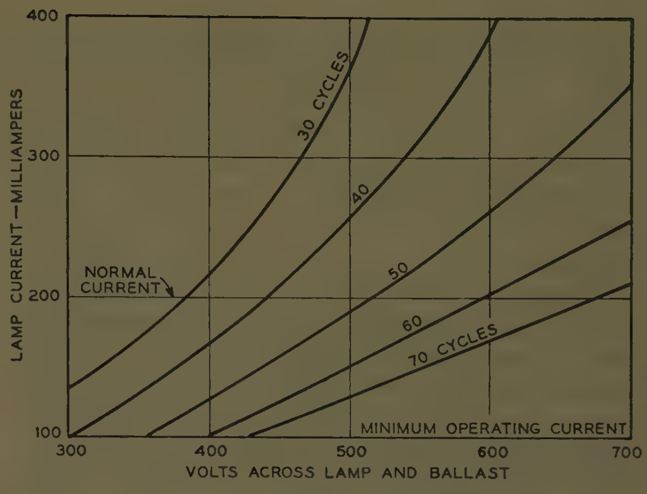


Figure 4. Variation of lamp current with voltage and frequency

72 T 8n Slimline fluorescent lamps with reactance ballast

series with an amplidyne mounted on the same armature shaft and in the same frame, a static voltage regulator of the saturable reactor type, and a step-type d-c motor starting panel. The amplidyne bucks or boosts the direct voltage from a medium value to maintain substantially constant alternating voltage at the slip rings of the inverter. Frequency variation is between 58 and 62 cycles with d-c battery potential of 105–160 volts for a 114-volt battery and corresponding voltages for a 64-volt battery. The control field of the amplidyne requires an output of approximately one watt from the static regulator, and the response is practically instantaneous with suddenly applied loads. The 6.25-kva machine is used on sleepers, parlor cars, and coaches. The 8-kva machine is for application on diners where additional a-c power is required for food storage locker refrigeration.

Development of fluorescent lights suitable for use on 60 volts direct current led to some demands for a booster that would step up power from a variable-voltage nominal 32-volt circuit to 60 volts. An ordinary motor-driven series booster can be used for this purpose but response is slow and control is bulky. A motor-driven amplidyne has been used to maintain 60 volts direct current for fluorescent lights. The field of the amplidyne requires very little power and it is, therefore, possible to control the field directly by means of a glow tube. This scheme could be used in place of the inefficient lamp regulator for 60-volt fluorescent lamps operating on 64-volt batteries. The higher cost of the equipment has been a factor in preventing any but a few experimental installations from being made.

The variable-voltage variable-frequency inverter may be used where relatively small motors are to be started from the a-c bus while fluorescent lamps are in operation or where larger motors do not have to be started while fluorescent lamps are in operation. It has been in successful operation on a Pennsylvania Railroad car since early 1945, supplying power to fluorescent lighting only.

A fluorescent lamp using an inductive ballast will take approximately the same current at different frequencies if the constant volts-per-cycle relationship is maintained (Figure 4). An alternator with fixed excitation driven by a d-c motor from a variable-voltage power supply therefore could operate over a wide range in speed within a somewhat less than proportional change in lamp intensity.

Because the alternating voltage of an inverted synchronous-converter (inverter) varies in proportion to the direct voltage input and because the speed of a shunt-excited inverter is a direct function of the applied direct voltage, a simple inverter may be used to supply power for fluorescent lighting from the variable direct voltage on railway passenger cars. The designer of the inverter can design for approximately constant volts per cycle in order to keep the lamp current reasonably constant for a wide variation in the voltage.

Where small batteries are used or when prolonged periods of running on the battery are necessary, it is desirable to design the inverter, so that the alternating voltage falls off more rapidly than the frequency to reduce the lamp load when the charging generators are not operating.

LOAD CHARACTERISTICS

Fluorescent lamps when operated on alternating current have a nonuniform stroboscopic light output caused by the cyclic variations in current, which becomes more noticeable as the frequency is decreased. A 2-lamp auxiliary is not satisfactory on a variable-voltage variable-frequency system because of a capacitor which is in series with one of the lamps. Therefore, with this system it is recommended that three phases be used to overcome the stroboscopic effect. A capacitor across the line can be used to give some control of the voltage-frequency relationship corresponding to different direct voltages.

The air horsepower demanded by a fan may be assumed to vary approximately as the cube of the speed, and for all practical purposes the speed of an induction motor will be directly proportional to the supply frequency. Torque of an induction motor varies as the square of the voltage. If the frequency applied to the induction motor is lowered from 60 cycles to 45 cycles at constant voltage, the motor will run at approximately 75 per cent of normal 60-cycle speed and the fan will require only 56 per cent of normal torque or 42 per cent of normal 60-cycle horsepower. The voltage could be reduced as much as 50 per cent without exceeding the pull-out torque on 45 cycles. Maximum torque at 45 cycles is greater than the maximum torque at 60 cycles because of the lower reactance on the lower frequency.

Operation of evaporator fans on the variable-voltage variable-frequency system has the advantage of reducing the fan load when the battery is not being charged. It also reduces the noise level of the fans at a time when the masking effect of train noise is absent. The make-up air taken into the car is reduced, and the total load on the air-conditioning system is reduced, giving further reduction of the electric load on the battery. Evaporator fans should run continuously to provide air circulation as long as the car is in use, so that the fluorescent lights will not be affected by frequent starting of the motors. The condenser fan motor should not be run on the variable-frequency supply because it will start frequently. A separate inverter would be required for any motors that draw relatively high starting current and have to start frequently on the same bus as fluorescent lights. The amplidyne-booster inverter is used in this case to provide the high speed regulating effect of the amplidyne.

New Type of Spectrograph

Valuable new information about the atom, offering more detail in the invisible infrared spectrum than ever has been approached, is made possible by the development of a new type of spectrograph by Doctor Richard C. Nelson of the department of physics at the Northwestern University Technological Institute, Evanston, Ill.

The new instrument enables scientists to extend their study of the light emitted by excited atoms from the present limit of 12,000 angstroms to 30,000. This extension of the range lies in the region of the invisible infrared or heat rays, which heretofore have been accessible only through difficult and time consuming measurements which limited the amount of information obtainable. Observations normally requiring one month now can be done in one hour.

The spectrograph, a combination of mirrors mounted on a heavy steel structural base, disperses the infrared radiation into its component wave lengths and passes it across a cell detector developed by R. J. Cashman, associate professor of physics at Northwestern University. The cell detector converts the radiant energy into electric energy and records it on a chart for convenient measurement. The spectrograph is the first instrument specifically designed and constructed for use in photoelectric recording of emission spectra. In recording the entire spectral region, Doctor Nelson's instrument spreads its findings on a 10-inch graph, a quarter of a mile long.

The infrared region is of particular interest to astronomers for obtaining information about relatively cold and hitherto invisible stars and has been used for determining the kinds of gases surrounding the planets as well as for investigating the outer prominences of the sun.

Walter R. Wilson, research associate at the Technological Institute, developed the electronic circuits which make possible the use of the Cashman cell detector.

The Engineering Profession in Transition

WILLIAM N. CAREY

This report by Colonel Carey, chairman of the Engineers' Joint Council Committee on the 1946 Survey of the Engineering Profession, reviews the highlights of the EJC's 1946 survey which is entitled "The Engineering Profession in Transition." The survey is soon to be published and will be available for general sale at $1 per copy. It is a continuation of previous work which covered the years 1929 to 1934, the present survey covering the years 1939 through 1946. Three articles reporting various phases of the former survey were published in ELECTRICAL ENGINEERING as follows: "Professional Aspects of Engineering Education," (EE, Aug '36, pp 863–7); "Unemployment in the Engineering Profession," (EE, Feb '37, pp 216–23); and "Employment in the Engineering Profession," (EE, May '37, 524–31). Of particular interest in this latest study, restricted for the first time to persons identified through their membership in the six national professional engineering societies as being qualified members of the profession, are the comparisons afforded for 1939, 1943, and 1946, indicating the economic status of the engineer before, during, and after the war years. The participating societies in this survey are: AIEE, American Society of Mechanical Engineers, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, and the American Institute of Chemical Engineers, which make up the Engineers' Joint Council, and the National Society of Professional Engineers, joining in this project by invitation of EJC.

IT BECOMES increasingly apparent that the 1946 survey of the engineering profession, now being published in an 80-page 9-by-12-inch Engineers' Joint Council bulletin under the title, "The Engineering Profession in Transition," will be a most valuable and interesting document to those in the profession. Dealing with the general and specific factors that affect engineers' employment opportunities and designed to establish relationship of earning capacity to these individual factors, the report covers the topics of geographical location, general field of employment and industry field, and includes a wide range of occupational statuses. Completion of the report marks a milestone of accomplishment in the co-operative professional activities of EJC. It furnishes the profession with up-to-the-minute economic status data based on answers to questionnaires sent to 87,000 professional engineers, all members of the six national engineering societies participating in the project.

Compilation of the report represents an expenditure by the engineer society group of $16,000 and more than that amount in addition in value derived through the co-operation of the Bureau of Labor Statistics, United States Department of Labor, which furnished staff and equipment for tabulating returns from the precoded questions. All members of the survey committee were called upon to give freely of their time to the project. In round numbers, the completed manuscript represents expenditures approximating a $50,000 total. These expenditures brought the report to the finished manuscript stage. Printing will be an additional expenditure to be met by the societies or by individuals desiring printed copies of the report.

Here it is possible to present only some of the more immediately interesting conclusions reached on the basis of replies received to the questionnaires, on which there was a 53 per cent return. The report must be read in its entirety for an appreciation of the completeness and clarity of the wealth of statistical information covering the engineering profession there presented.

A marked change occurred in the ratio between the earnings of the older and the younger members of the engineering profession over the period 1939 to 1946. In 1939, private graduate employees with 35 to 39 years experience earned a median salary of $550 a month, which is nearly $4^1/_2$ times greater than the median $127 a month for newcomers to the profession in that year. In 1946 the corresponding difference in median salaries in this same grouping was $629 to $232, a ratio of $2^3/_4$ to 1 as against $4^1/_2$ to 1 in 1939.

The report also establishes clearly that graduate engineers earn more than nongraduate engineers at all experience levels except for the first six years. Consistent with this is the fact that those with master degrees earn more than those with bachelor degrees, and graduates with the degree of doctor enjoy still higher earnings.

Another significant development is that the monthly salary rates structure of the engineering profession in 1946, with overtime payments no longer a factor, not

William N. Carey, as executive secretary of the American Society of Civil Engineers, is a member of the Council in the Engineers' Joint Council. He is vice-chairman of the Committee on the Economic Status of the Engineer, and chairman of one of its subcommittees, the Committee on the 1946 Survey of the Engineering Profession.

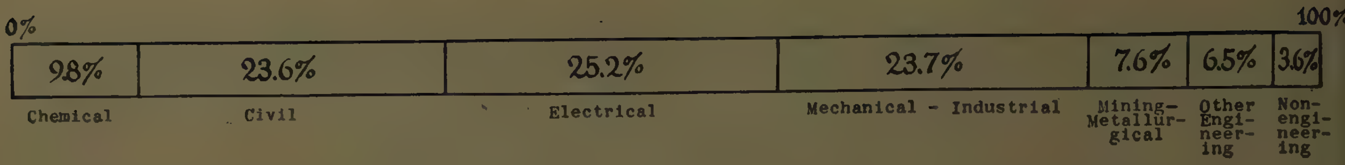


Figure 1. Percentage distribution of the engineering profession in 1946 by general field of employment

only was much higher than that of 1939, but also exceeded the base-plus-overtime range of 1943. Further, this improved earnings status in 1946 was common to engineers in all general fields of employment, whether graduates or nongraduates, and in both private and public engineering.

Younger engineers reported the greatest relative increases. For newcomers to the profession in 1946 the improvement was of the order of 88 per cent, reflecting median monthly salary rates of $231 a month for 1946 as against $128 a month in 1939. Men with 6 and 12 to 14 years' experience received median rates in 1946 of $343, and $385 a month or, respectively, 60 and 33 per cent more than similarly experienced engineers had received in 1939.

Interesting data are revealed in the report regarding the differential which begins to assert itself between graduate engineers and nongraduates after the first six years of experience. During this period, as has been stated, the differential is negligible. At the 9 to 11 years' experience level in 1946, engineers with bachelor degrees reported median earnings of $389 a month, whereas engineers with incomplete college courses or no college education reported, respectively, $363 and $374 a month. By contrast, while masters earned $409 a month, doctors earned as much as $466 a month. Significantly, at higher experience levels, the earnings' advantage in favor of graduates becomes more and more pronounced.

The report shows that the profession in 1946 was not a "closed shop" for graduates only. This is evidenced by the fact that 17 per cent of all engineers reporting included men who had incomplete college training or none at all. Bachelor degrees were held by 64 per cent, while 15 per cent reported graduation at the master's level and 4 per cent were doctors.

Really significant differences in engineers' earnings begin to appear only beyond the eight years' experience span (that is, 31 years of age). The extent of these differences, as might be expected, depends largely on the general field of employment of the individual, educational qualifications, and occupational assignment. For example, in 1946, median base monthly salary rates ranged from $224 to $256 a month among 10 groups of newcomers to the profession, 6 groups engaged as employees in private, and 4 in public engineering. By contrast, among the six private engineering groups the range in median rates earned by engineers with from 35 to 39 years' experience span was from $513 a month for civil engineers to $825 a month for chemical engineers. Second in ranking order came mining–metallurgical engineers with $693 a month, followed by $650 a month for men in "other engineering fields," electrical engineers with $604 a month, and $587 a month in the case of mechanical–industrial engineers. This steady progression in earning capacity with advancing years of experience also is characterized by a persistent and substantial spread in earnings at every experience level. This spread becomes particularly accentuated in the upper 10 and 25 per cent earnings groups.

The composition of the profession in 1946 by general field of employment showed nearly 73 per cent about equally divided among civil, electrical, and mechanical–industrial engineers. There were 10 per cent chemical engineers, 7 per cent mining–metallurgical, 6 per cent in other engineering fields, and the remaining 4 per cent were engaged in nonengineering work. Except for civil engineers, whose work was divided approximately equally between public and private engineering, those in the other six fields were overwhelmingly dependent upon private engineering for their employment. Nearly 60 per cent of the country's professional engineers in 1946 were in the manufacturing and construction industries.

Among the 29 occupational statuses reported for 1946,

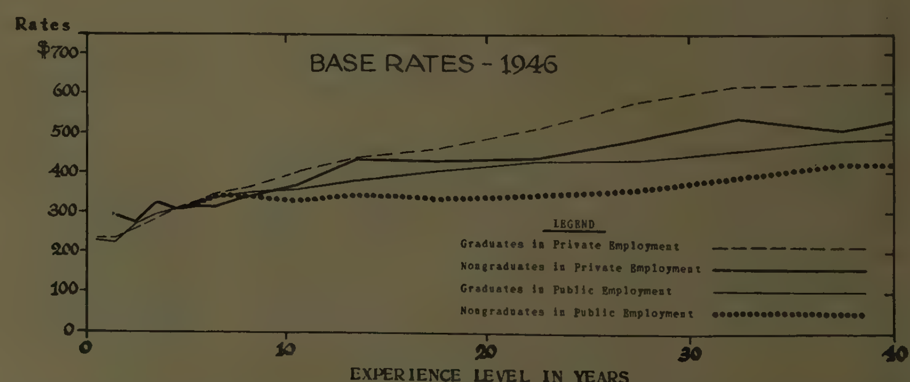


Figure 2. Median base and base plus overtime monthly salary rates of graduate and nongraduate engineers in private and public employment in 1946, 1943, and 1939

nearly 30 per cent of all engineers were engaged in technical administration-management. Design, development, and applied research attracted 15, 7, and 5 per cent, respectively; supervisory construction, college or university teaching, private firm consulting, and sales each included from 4 per cent to 5 per cent. Among the remaining 21 statuses, the percentages ranged from less than 1 per cent to 4 per cent.

When related to each of the 29 occupational statuses, the median monthly salary rates among the newcomers to the profession in 1946 ranged only from $206 to $248. At the six years' experience mark, the range had increased from $280 to $378 a month. But at the 12 to 14 years' experience level, while engineers engaged in routine work, such as drafting, earned $310 a month in 1946, men engaged in nontechnical administration-management earned as much as $555 a month.

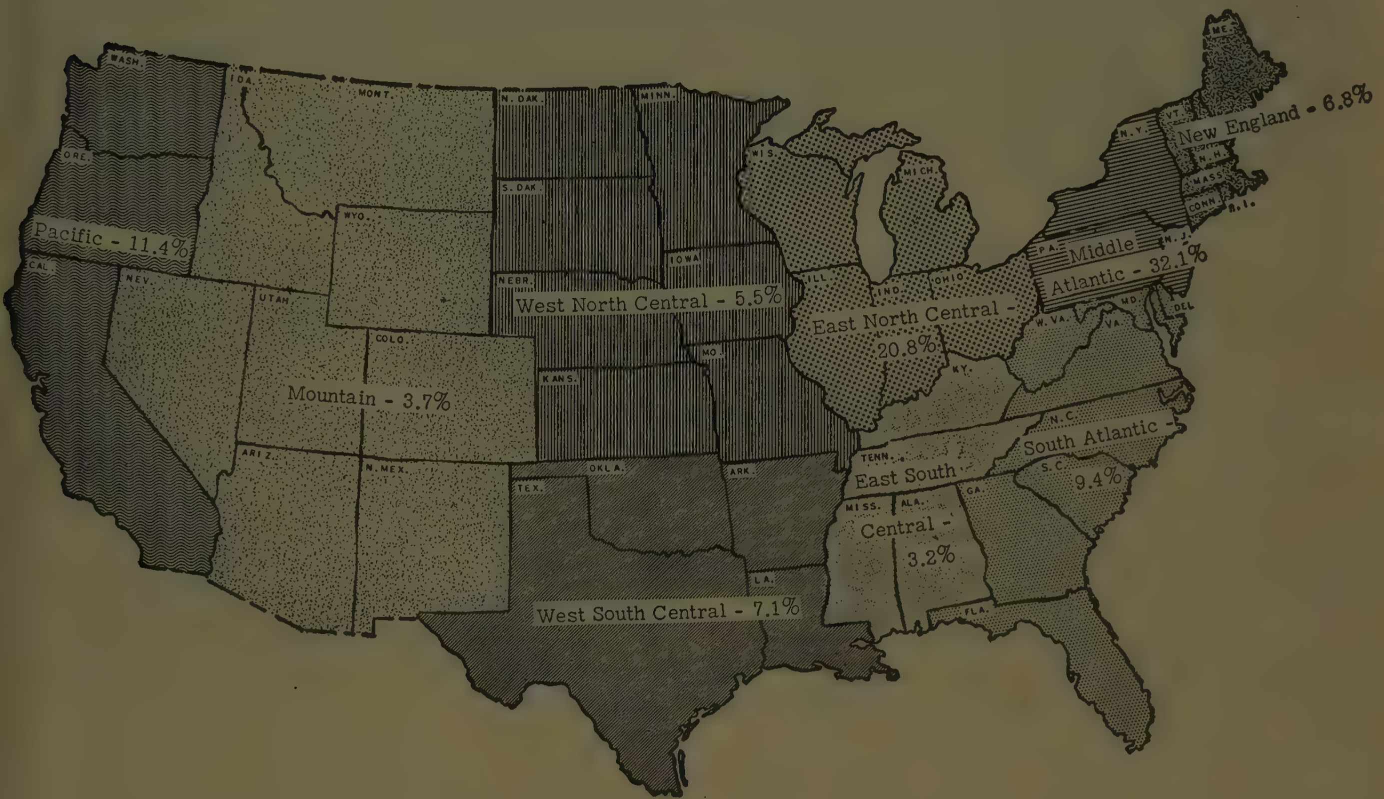
The relationships found to exist between earned annual incomes reported for 1939 and 1943 only, and monthly salary rates in these same years, make it clear that the opportunity to earn substantially more than base salaries is confined to a very small and experienced segment of the profession.

An earnings differential pattern that persisted to the end of the active experience cycle of professional engineers is disclosed by the 1946 information. This begins at the 15 to 19 years' experience mark and indicates that, at the median earnings point, civil engineers generally receive the lowest remuneration, not only in private engineering, but also in nonfederal Government employment in public engineering. Furthermore, the earnings of engineers in private engineering employment exceed by far those reported for public engineering, with private chemical engineer employees consistently reporting the highest remuneration at all experience levels.

Though the median monthly salary rate for newcomers in the civil engineering field is the highest of all, it is the lowest at the 40-year experience level. The median rates of civil engineers steadily increased from $243 for newcomers to $513 for men with 35 to 39 years of experience while engineers in "other engineering fields" increased from $224 to $650 a month. The corresponding range for chemical engineers was from $256 to as high as $825. Between the two extremes came mining–metallurgical engineers with median earnings that increased at the same experience levels from $236 to $693 a month, and below the "other engineering" group, but above the civil engineers, were the electrical engineers, whose reported median earnings increased from $237 for newcomers to $604 at the 35–39 years experience level, and the mechanical–industrial engineers who had a corresponding experience span increase from $225 to $587 a month.

Perusual of employee engineers earnings indicates that they must be modified when related to educational qualifications. For example, the median earnings of the graduate group in 1946 increased from $232 a month to $346 a month over the experience spans 1 to 6 years,

Figure 3. Geographical distribution of the engineering profession in 1946



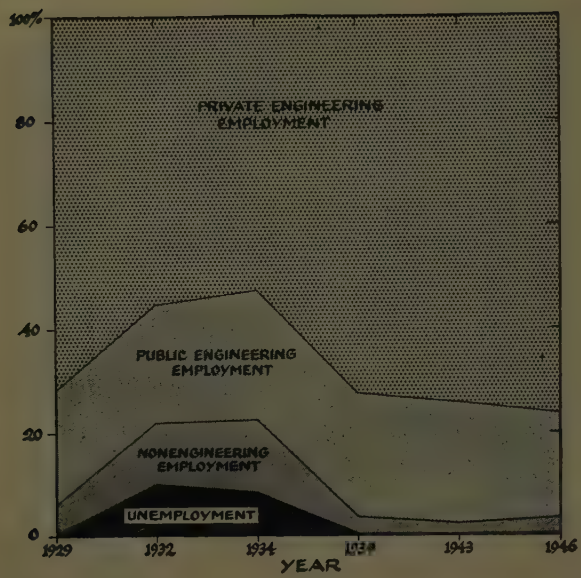


Figure 4. The class of worker status of the engineering profession, 1929–1946

whereas the median earnings of the comparable group of nongraduate engineers increased from $295 to $317 a month. At the 7 to 8 years' experience mark, nongraduate private employees earned $344 a month, but graduate private employees earned a median rate of as much as $365 a month. In public engineering, the earnings differential in favor of graduates does not assume statistical importance until the 9 to 11 years' experience level is reached.

As to World War II, the survey points up the fact that approximately 12 per cent of all professional engineers in the country served in the Armed Forces. A breakdown of this figure indicates that the war effort required mining engineers and chemical engineers generally to remain in civilian status, or, if in the Armed Services, to follow pursuits outside their professional fields. More civil engineers served in their field in the armed services than any other group. The breakdown of professional engineers in the services in World War II is: civil, 29 per cent; mechanical–industrial, 15 per cent; electrical, 14.7 per cent; chemical, 1.8 per cent; mining, 1.0 per cent; other engineering, 14.2 per cent; and nonengineering, 24.3 per cent.

Comparisons also confirm what might be assumed, that the demands of the services were for younger men. Apparently the services utilized professional engineering skills to a high degree. The effects of demobilization were such that the patterns of disposition with respect to the class of worker and industry field were virtually the same in 1946 as had existed seven years earlier in 1939. The changing pattern with respect to occupational status reflects the advance which occurred in engineers' over-all economic status, despite service either in the Armed Forces or as civilians. As to comparative earnings between engineers in the Armed Forces in 1943 and those who were civilians, the survey indicates that base median monthly rates were approximately the same at each respective experience level for the two groups.

A wealth of additional information is contained in the report which goes into employment opportunities by geographical location and general fields of employment. In this brief résumé, it has been attempted merely to present some indication of the magnitude and scope of the survey. A reading of the full report is required for full appreciation of the completeness and clarity of the statistical information covering the engineering profession.

The report will do much toward increasing the tempo of studies and discussions on the need for reorientation of engineering education and practice which have been under way in many quarters. In short, the 1946 survey of the engineering profession, so aptly titled, "The Engineering Profession in Transition" is, to state it rather unprofessionally, the "where we have been" on the economic status of the engineering profession, which can serve as an important, factual guide to "where do we go from here?"

Electrical Essay

The following electrical essay is presented for the recreation of the reader. The author's challenge is to determine whether these statements are true or false.

In an *electrostatic* field, a line of force meeting the smooth surface of a perfect conductor is always perpendicular to that surface. *True* or *false?*

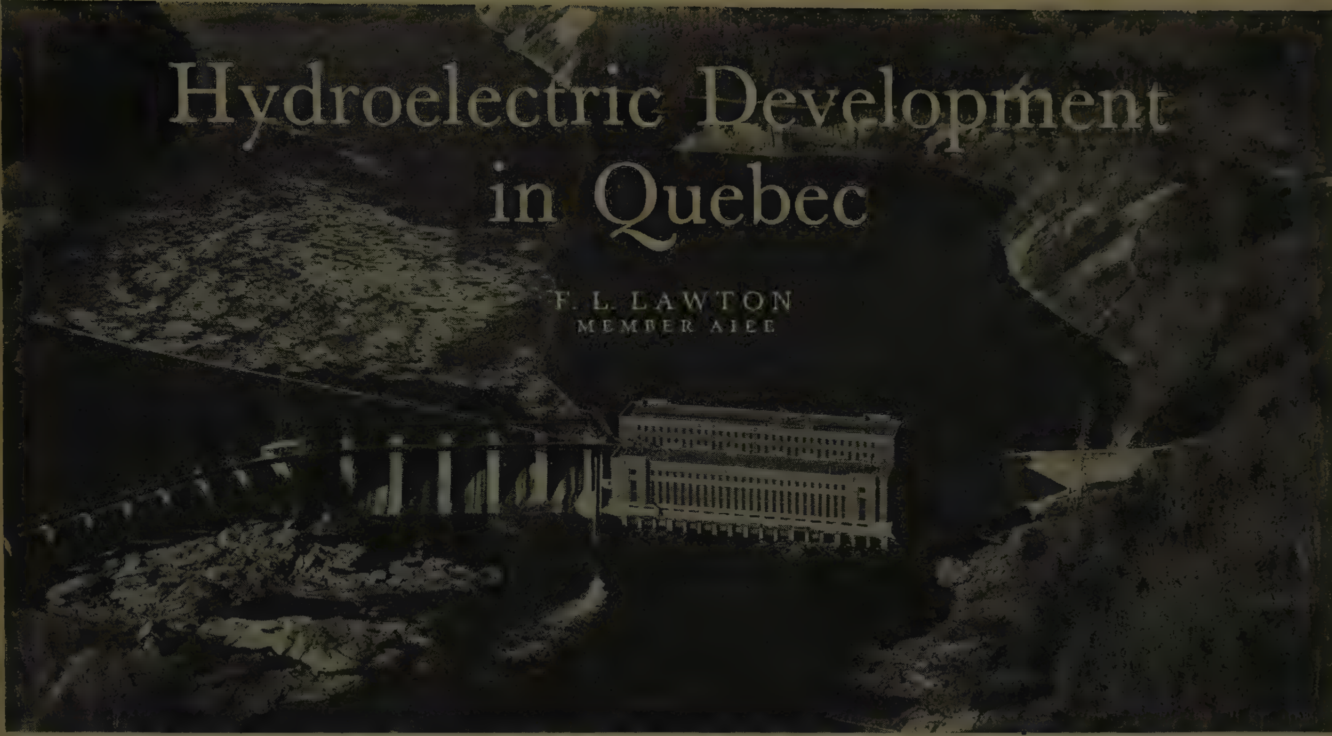
A rod of diamagnetic material, mounted so that it can turn freely, will set itself perpendicular to the direction of a uniform magnetic field in which it is placed. *True* or *false?*

JOSEPH SLEPIAN (F '27)

(Associate director, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.)

Hydroelectric Development in Quebec

F. L. LAWTON
MEMBER AIEE



Aerial view of La Gabelle power plant courtesy Canadian Pacific Air Lines

Quebec, with an area of almost 600,000 square miles, is the largest province in the Dominion of Canada. Second only to Ontario in population and industrial development, it has no known deposits of coal or oil. Quebec owes its rapid industrial growth to its great hydroelectric power systems developed by private enterprise, although the government has made an important contribution through the work of the Quebec Streams Commission in constructing storage reservoirs.

QUEBEC'S unique power development, in which not a single kilowatt of steam power is generated, includes one of the greatest hydroelectric power pools in the world, the 4,000,000-horsepower Montreal-Shawinigan-Saguenay interconnected system. It is also noted for its great electric-steam-generator load, and the notable Beauharnois, Isle Maligne, and Shipshaw developments.

Generally speaking, Quebec (Figure 1) is not a region of high relief. Principal topographic divisions are the Laurentian plateau, the St. Lawrence lowlands, and the Appalachian region.

The Laurentian plateau region comprises the portion of Quebec north of the St. Lawrence and Ottawa rivers, more than 90 per cent of the province. The surface is cut by many streams with numerous lakes and swamps. A striking feature of the region is the generally disorganized drainage. The plateau is drained toward the St. Lawrence River by 13 rivers over 100 miles long, toward Hudson Bay by 14 rivers over 100 miles long, and toward Hudson Strait by 3 rivers over 350 miles long. Near the headwaters of these three groups of rivers the relatively ill-defined drainage will permit extensive diversion of water from one watershed to another, which ultimately will permit a significant addition to the economically utilizable water powers of the province.

The St. Lawrence lowlands comprise the V-shaped plain which lies south of the Laurentian plateau and extends on either side of the St. Lawrence River from the region of Quebec City to the western boundary of the province, with an arm running up the Ottawa River. The lowlands cover an area of about 15,000 square miles, the principal agricultural area of Quebec.

The Appalachian highlands comprise the hilly region lying south of the St. Lawrence lowlands, with an area somewhat less than 40,000 square miles. It is the most rugged area of the province with numerous mountains over 3,500 feet.

Numerous streams drain the St. Lawrence lowlands and the Appalachian highlands, but on the south bank of the St. Lawrence, there are only three rivers of any great significance.

PRECIPITATION

Average annual rainfall in Quebec is about 36 inches, including snow which averages about 100 inches, equiva-

Essential substance of paper 47-124, "Hydroelectric Power Development in Quebec," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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Figure 1. Province of Quebec showing geographic distribution of water powers

lent to approximately 10 inches of rainfall. Runoff averages about 50 per cent of precipitation. Rainfall, temperature, and other useful meteorological data are obtained from some 100 stations distributed throughout the province, the majority of these stations being in charge of power, industrial, and pulp and paper companies. Observers record the data and transmit it to the Quebec Streams Commission which works in close co-operation with the Meteorological Service of Canada.

RUNOFF

Average yearly runoff from Quebec rivers is about 1.6 cubic feet per second per square mile of drainage area.

Beginning in 1913, systematic flow measurements of the principal rivers have been made, the establishment, observation, and maintenance of gauges being largely a co-operative undertaking on the part of power utilities, pulp and paper companies, and the Quebec Streams Commission. Since 1922 stream measurements have been carried out by the Dominion Water Power Branch, which works in close co-operation with the Commission, so that fully co-ordinated data on river flow is available.

WATER POWERS

The water powers of Quebec, based on ordinary six months flow, and 80 per cent efficiency, total about 13,073,000 horsepower. Table I is a tabulation of water powers available on each of the major watersheds. Estimates of power on the basis of ordinary six months flow are made upon the assumption it is good commercial practice to provide an installation of such capacity that continuous operation can be assured six months in the year, with the deficiency in output during the remainder of the year provided from storage, interconnection with other plants on rivers of different regimen or operating under different load conditions, or parallel operation with fuel-burning power plants. An analysis of Canadian practice shows that, on the average, the usual water wheel installation has a capacity of 1.3 times that corresponding to the ordinary six months flow. In Quebec, principal reliance has been placed on storage, with system interconnection next in importance. There are no fuel-burning plants associated with Quebec's hydroelectric power systems.

Developed water powers, as at January 1, 1946, totaled 5,848,572-horsepower installed capacity, 57 per cent of the Canadian total and well over twice that for Ontario (Figure 2). This installed capacity is equivalent to 1,643 horsepower per 1,000 population. Central electric stations for general public service, pulp and paper industries, and electrochemical and electrometallurgical industries account for 92.96 per cent of the installed capacity, and the remaining 7.04 per cent is in direct-connected applications.

Developed water powers in Quebec, aside from scattered plants, fall into several major groupings as follows: Gatineau River, Lièvre River, Ottawa River, Saguenay River, St. Lawrence River, and St. Maurice River. Total power development on these six rivers is 5,388,423 horsepower, some 92.1 per cent of the total hydroelectric power development in Quebec.

STORAGE

Storage is essential to optimum development of practically all water powers in Quebec, with the exception of the St. Lawrence, which is endowed with a remarkably uniform flow due to the great natural storage of the Great Lakes.

Storage reservoirs in Quebec fall into three categories:

1. Those built and operated by the Quebec Streams Commission.

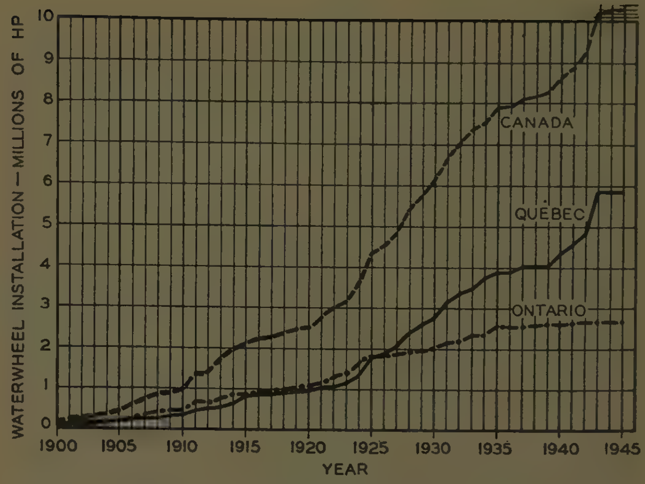


Figure 2. Installed water wheel capacity in Ontario, Quebec, and Canada

2. Those built by power companies and operated by the Quebec Streams Commission.
3. Those built and operated by power companies.

In the case of storage reservoirs built and operated by the Commission, power companies benefiting from the additional flow provided must pay for such.

Operating experience with large storage reservoirs located 150–200 miles or more from the power plants at which the water is used shows very small losses of storage water in the form of ice, despite the rigorous winter conditions in the Quebec hinterland, where the temperature frequently falls below minus 30 degrees Fahrenheit for a week or so.

DEVELOPMENT OF WATER POWER

The early history of hydroelectric development in Quebec was characterized by the construction of isolated plants at favorable sites close to power markets or where markets could be developed. As markets expanded, developments entailing a fully co-ordinated program of construction for an entire river, embracing both power

Table I. Waterpowers of Quebec Province

Ordinary 6-Month Flow, 80 Per Cent Efficiency

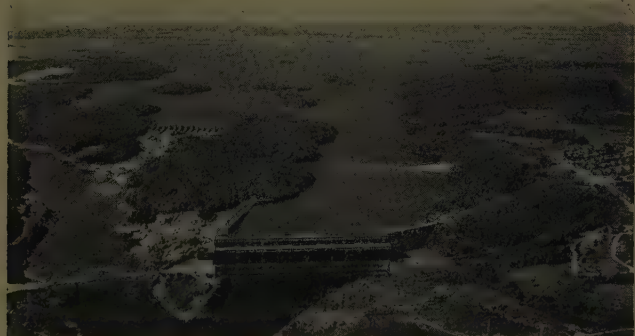
River or Watershed	Water Power Capacity, Horsepower	
St. Lawrence (Ontario boundary to Montreal)	2,340,000	
Ottawa	1,602,505	
Saguenay	1,534,008	
St. Lawrence tributaries—north shore	3,819,881	
south shore	303,598	
St. Lawrence watershed		9,599,992
James Bay	2,445,287	
Hudson Bay	500,669	
Hudson Bay watershed		2,945,956
Ungava		521,800
Chaleur Bay		4,534
St. John		267
		13,072,549

plants and storage came into being. Typical of these river developments are the Gatineau, Lièvre, Saguenay, and St. Maurice systems. The Ottawa and the St. Lawrence, while they ultimately will be exploited fully, do not present the same degree of co-ordination because of the multiplicity of interests involved. In the relatively undeveloped areas of Quebec there are isolated plants serving newsprint and mining industries.

The Gatineau River was unimproved until 1925, when a power development was started making economically feasible a co-ordinated installation of 562,000 horsepower of which 528,000 horsepower now is installed.

Prior to 1928, the only power development on the Lièvre river was at Buckingham consisting of water wheels with a capacity of about 6,600 horsepower. The river now sustains approximately 283,000-horsepower generating capacity.

The Ottawa river, over the greater part of its course, constitutes the boundary between Ontario and Quebec and, as such, its water powers are divided. With an estimated capacity of some 1,310,310 horsepower at ordinary six months flow and 80 per cent efficiency, only about 401,000-horsepower capacity is installed, of which about 239,800 horsepower is in Quebec.



Courtesy Canadian Pacific Air Lines

Figure 3. Aerial view of Isle Maligne power development

The Saguenay hydroelectric power system consists of two separate power developments utilizing the full head available on the Saguenay river between Lake St. John and tidewater. The up-river development is that of the Saguenay Power Company, Ltd., located at Isle Maligne (Figure 3). When placed in service in 1925, with an initial eight units each rated 45,000 horsepower, Isle Maligne was one of the largest single-stage hydroelectric power plants in the world. It now has a capacity of 540,000 horsepower. The down-river power development, owned by Aluminum Company of Canada, Ltd., was constructed in two steps. Shipshaw Number 1 with a capacity of 300,000 horsepower in four units was placed in service in 1931. The twelfth and last unit of Shipshaw Number 2 went into service on December 24, 1943. Taking its water from the same forebay as Shipshaw Number 1, Shipshaw Number 2 has a capacity of 1,200,000 horsepower. Probably the most outstanding feature of Shipshaw Number 2 was the speed with which it was constructed and placed in service, at a time when Canadian manufacturing resources were geared to the production of war material for the United Nations.

The initial power development on the St. Maurice River was that at Shawinigan Falls, put under construction in 1900. The St. Maurice river presents, in somewhat less than 50 years, a co-ordinated river development with an installed water wheel capacity of some 1,130,550 horsepower and a regulated flow of 3.5 times the minimum natural flow.

Another outstanding hydroelectric plant is that at Beauharnois, located less than 25 miles from Montreal, which when completed will have a capacity of 2,000,000 horsepower in one station. It probably will become and remain for a long time the largest hydroelectric station in the world, although it may be surpassed ultimately by the projected development in the Yangtze Kiang gorge, in China. The complete station is supplied by a 3,000-foot wide diversion canal, which is an integral unit of the projected St. Lawrence Seaway and is planned to carry the ultimate diverted flow of 220,000 cubic feet per second.

LOADS

Aside from general industrial, commercial, and domestic load in the metropolitan areas, and manufacturing communities, the extensive development of water power in Quebec (Figure 5) is attributable to the rise of newsprint and associated manufactures, and, in the Saguenay area aluminum production. Export of power to Ontario also has played a substantial part during the last quarter century.

The Gatineau Power Company system supplies a very large newsprint and other wood-products load, in addition to which a very substantial block of 25-cycle power is transmitted at 220 kv to the Toronto area. The present system yearly peak demand is 445 megawatts with installed electric-steam-generator capacity of 180 megawatts.

The Lièvre developments of the Maclaren-Quebec Power Company supply, for the greater part, the newsprint industry and export a large block of 25-cycle power at 220 kv to the Toronto area.

While most of the smaller water power plants on the Ottawa river furnish power for newsprint and associated manufactures, the Quinze and Rapid 7 power developments supply the mining districts near by. The output of the 224,000-horsepower Chats Falls plant goes entirely to the 25-cycle Toronto system of the Hydro-Electric Power Commission of Ontario, aside from a 60-cycle block fed through a frequency changer to their Eastern Ontario system.

The Saguenay system load consists of aluminum-smelting and paper-mill loads, and a relatively small general public service. The system primary load comprises a

peak demand of 900 megawatts for aluminum production, 100 megawatts for pulp and paper, and a block of 75 megawatts transmitted to the Shawinigan system. Daily system load factors are in the vicinity of 95 per cent. During periods of high and normal river flow or when aluminum production is below full capacity, loads up to 375 megawatts are supplied to electric steam generators.

The Shawinigan area not only is the principal agricultural area of Quebec but also contains a wealth of diversified light and heavy industrial undertakings. This area is served mainly by the Shawinigan Water and Power Company, the Quebec Power Company, and the Southern Canada Power Company. As much as 500,000-horsepower peak of secondary power during flush-water periods has been sold to paper mills, thus replacing very substantial amounts of coal-produced steam. A very limited part of the system is supplied at 30 cycles.

The Montreal area is supplied from the Beauharnois, Cedar Rapids, and St. Timothé plants on the St. Lawrence, the Back River plant on the Ottawa, and over four 110-kv lines from Shawinigan Falls (Figure 6).

TRANSMISSION NETWORKS

As most power stations in Quebec are relatively remote from the load areas, quite extensive transmission networks are necessary for the transmission of power. Practically all lines are 220 kv, 154 kv, 110 kv, or 60 kv, and overhead construction is usual, except in the Montreal area where 60- and 120-kv underground cables are used. Double-circuit construction is quite customary, except for the 220-kv lines and where limited load requirements obviate the necessity of the additional circuit.

In general, overhead lines are designed for one-half-inch ice and 8 pounds per foot wind loading at zero degrees Fahrenheit. Ground wires usually are provided for shielding against direct strokes, and buried counterpoise is being used more widely, because of the high earth resistivity caused by the rocky nature of much of the area traversed by overhead lines which makes for relatively expensive and unsatisfactory counterpoise installations. However, the frequency of lightning storms is moderate, ranging from about 17 per year in the Saguenay area to about 40 per year on the more exposed transmission links of the Shawinigan system. By far the greater part of all transmission lines in Quebec have aluminum-cable steel-reinforced conductors.

Prior to World War II, the Montreal area was served by a 60-kv double-ring transmission network, mostly overhead construction but with important underground cable links. The close linking of the Montreal-Shawinigan-Saguenay systems during the war, in order to utilize to the fullest possible extent all the energy resources of the combined systems for the production of aluminum, was, in part, accomplished by the installation, by the Aluminum Company of Canada, of a 115-kv oil-filled underground cable about 34,600 feet long.

INTERCONNECTION

It long has been recognized by system engineers of Quebec power utilities that there are many advantages in interconnected operation with adjacent systems such as:

1. Better regulation of load, frequency, and voltage.
2. Optimum utilization of surplus energy.
3. Lower total reserve generating capacity requirements.
4. Full advantage can be taken of diversity in loads and hydraulic conditions.
5. Additional generating capacity can be added at the most economical location.
6. Equipment maintenance can be scheduled to better advantage.

The interconnected 60-cycle hydroelectric system of the Saguenay Power Company, the Aluminum Company of Canada, the Shawinigan Water and Power Company, and Quebec Hydro-Electric Commission, with a combined capacity of some 4,000,000 horsepower comprises 16 major generating stations of 20,000–1,200,000-horsepower capacity, in addition to numerous smaller stations. About 3,700,000 horsepower, of the connected total, normally is operated in parallel.

Courtesy Canadian Pacific Air Lines

Figure 4. Aerial view of 200,000-horsepower Rapide Blanc power plant

The Montreal system, as previously noted, is characterized by the relatively constant power generating capability of the St. Lawrence power plants, which have excellent natural storage capacity, and the low-load-factor metropolitan load. The Shawinigan system, with its large storages and regulating possibilities on the St. Maurice river, could convert a major portion of the available surplus energy into firm power.

In the Saguenay area, generator capacity normally available during the winter months also could be used in the conversion of surplus night energy of the Montreal system into firm power by storage in Lake St. John. Surplus summer energy could be stored in the St. Maurice reservoirs and converted into winter firm power.

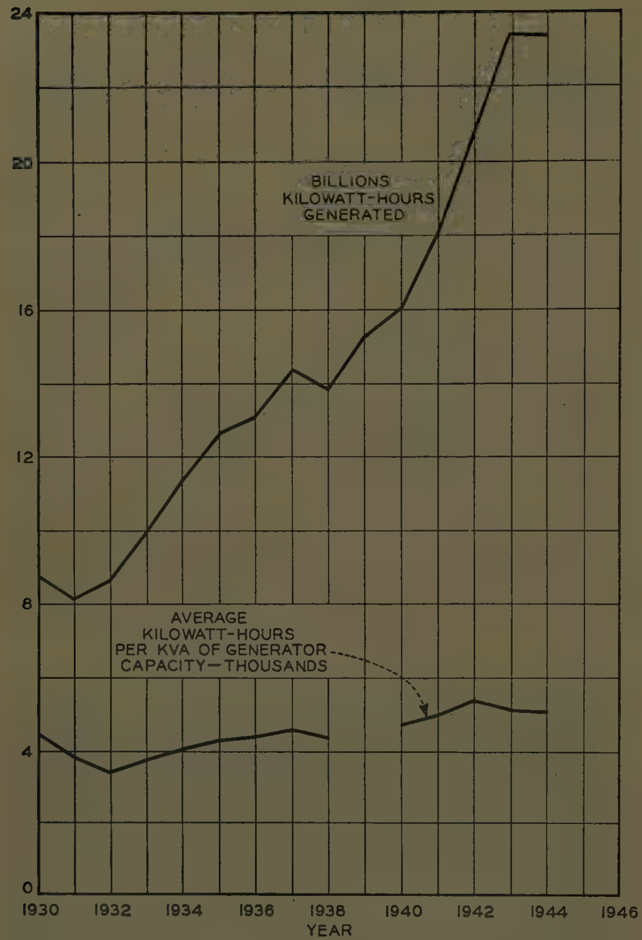


Figure 5. Growth of hydroelectric energy generation in Quebec

The outbreak of war in 1939 resulted in greatly increased firm-power loads for the production of aluminum and other war material, especially in the Saguenay and Shawinigan areas. Interconnection of the Montreal, Shawinigan, and Saguenay systems to the optimum economical extent provided the maximum of firm power from the energy resources of the combined systems in the shortest possible time. Some 825,000,000 kilowatt-hours of surplus energy were converted into firm power by utilizing Shawinigan storage facilities. This necessitated the provision of the 115-kv oil-filled cable tie across the city of Montreal, as previously discussed, which increased the transfer ability by over 100 megawatts.

To handle the increased flow of surplus energy from the Montreal area, store part of it, and transmit the remainder to the Saguenay system, it was necessary to: provide additional transformers and voltage-regulating equipment on the Shawinigan system, provide additional storage on the St. Maurice river, and construct a 220-kv tie line interconnecting the Saguenay system with the Shawinigan and Montreal systems. Operation of the interconnected system has been very successful, and despite the heavy loading of the long ties, the transient stability is good.

PROGRESS IN DESIGN

Considerable progress in the development of improved water-wheel-runner designs has been effected by hydroelectric engineers in Quebec. Outstanding work in this connection has been done in the hydraulic testing laboratory of the Shawinigan Water and Power Company at Shawinigan Falls. The runners in the Shipshaw Number 2 plant have developed the very high maximum efficiency of 94.5 per cent (Figure 7). The use of welding in the field assembly of the scroll-cases for the Shipshaw units proved most satisfactory, and contributed materially to the high efficiency obtained. All newer water wheels in Quebec have been made in cast steel, eliminating the tendency to fatigue cracking with cast-iron designs and permitting easier repairs in the case of pitting. Definite improvements in repair methods used for maintenance of pitted runners have been effected.

Progress in improved water wheel designs has been paralleled by progress in the direction of generator designs. Newer units, particularly the larger ones, are

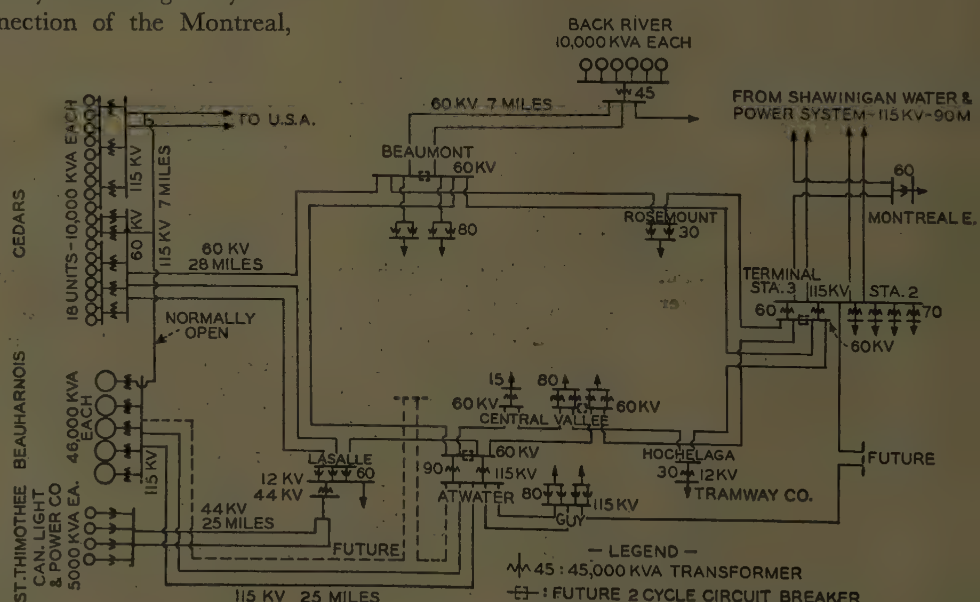


Figure 6. Montreal system diagram

being provided with closed ventilating systems and water cooling.

ICE TROUBLES

Despite low temperatures which are prevalent during the winter season in Quebec, little trouble is experienced with ice. The reason for this is that hydraulic engineers early appreciated the necessity of limiting velocities of approach to racks and through head channels to such values that an ice cover would form early in the winter season, providing pondages of such extent and depth that rapids immediately above power plants would be eliminated, providing deep skimmer or curtain walls at intakes. In some cases, it has not proved practical to eliminate ice troubles completely, from both frazil and floe ice. At one or two developments heated trash racks have proved to be the solution to ice troubles.

Where spillway and sluice gates must be operated during freezing weather at storage reservoirs, heaters are employed. At some storage dams at relatively high altitudes, and in remote locations, steam boilers have been installed as a stand-by means of clearing ice.

OPERATION

Notable strides have been made in Quebec in utilization of available energy resources to the optimum extent, by proper scheduling of water release from remote storage dams, where a delay of a few days before water is received at the plant of use must be taken into account. Use of available water to obtain maximum energy output is effected by proper division of load among units in accordance with output-discharge curves derived from efficiency tests by the Gibson and salt-velocity methods. Responsibility for working out such optimum usage of water is placed with technically qualified system operating engineers, who work in close conjunction with hydraulic and electric engineers fully familiar with the characteristics of the units and the whole development.

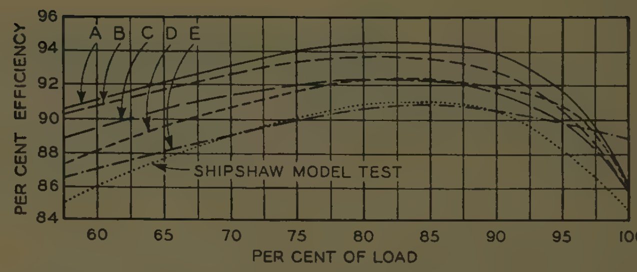
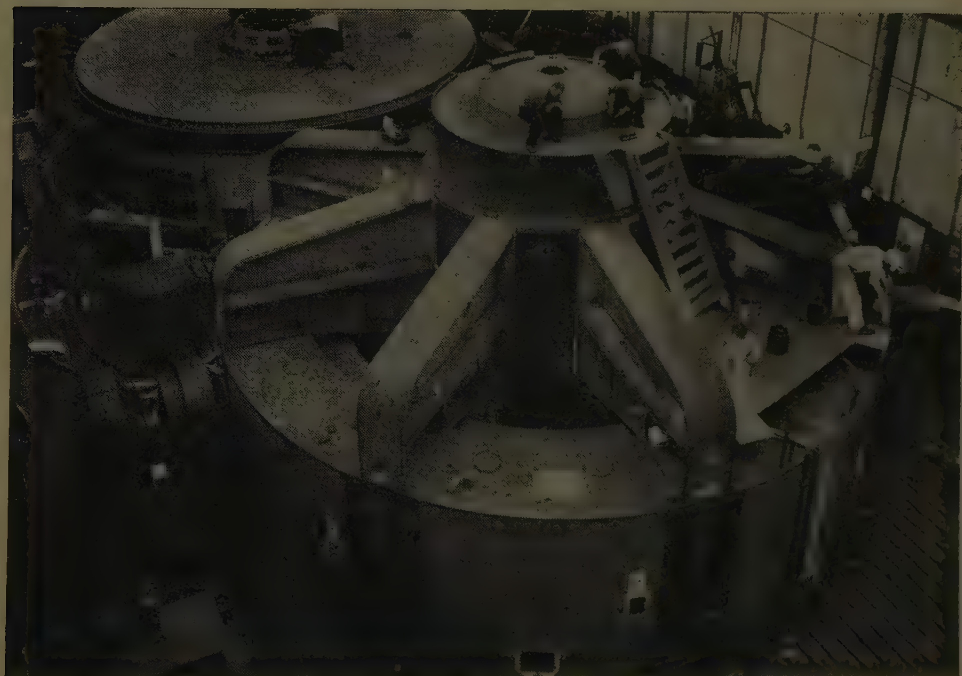


Figure 7. Efficiency curves for outstanding North American water wheels

A—Shipshaw unit 9 *C—Grand Coulee unit L7*
B—Niagara unit 21 *D—Osage unit 3*
E—Boulder unit 5

Grand Coulee Generators



This 108,000-kw generator is one of seven built by the Westinghouse Electric Corporation for Grand Coulee Dam. Said to be the largest water wheel generators ever built, they are 45 feet in diameter, 32 feet in height, and weigh two million pounds

Electric Power Sources

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Sources of electric power may be divided into 11 major classifications. These classifications are outlined and briefly described herein.

STRICTLY SPEAKING, devices for producing electric power are not power sources but rather power or energy converters. The various known methods of producing electric power may be divided into 11 major classes:

1. Electromagnetic.
2. Electrochemical (electric batteries).
3. Electrostatic.
4. Thermoelectric (thermopiles).
5. Thermomagnetic.
6. Magnetostrictive.
7. Piezoelectric.
8. Electric emission.
9. Contact.
10. Atmospheric.
11. Terrestrial (earth currents).

It should be understood that the foregoing classifications are purely arbitrary. With the appearance of other articles dealing specifically with each method by an authority in that field, a reclassification of the various methods may be found desirable.

ELECTROMAGNETIC GENERATORS

In this article an electromagnetic generator is defined as a generator which converts mechanical power to electric power by mechanically changing (usually by rotation) the magnetic flux linking an electric circuit.

Electromagnetic generators may be divided into a number of types depending upon their construction and operating characteristics. Figure 1 is a block diagram of these various classifications.

With the exception of some types of acyclic (homopolar or unipolar) generators, the electromotive force produced in the armature is alternating. Direct current is obtained from such an armature by means of a commutator. The armature may be defined as being the electric circuit in the generator through which the flux linkages are changed to produce an electromotive force; whereas the magnetic circuit which produces the magnetic flux is defined as the field. The field may be electromagnetic or it may consist of a permanent magnet core.

Essential substance of a conference paper presented at the AIEE winter meeting, New York, N. Y., January 27–31, 1947.

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The authors express their appreciation to the United States Army Signal Corps and to the members of the Armour Research Foundation participating in the survey upon which much of the material in this article is based.

Electromagnetic generators may be divided into two broad general groups, namely: alternating current and direct current. In turn, the a-c generators include the following types:

1. Single-phase synchronous generator.
2. Polyphase synchronous generator.
3. Inductor-type synchronous generator.
4. Revolving field.
5. Revolving armature.
6. Single-winding synchronous generator.
7. Multiple-winding synchronous generator.
8. Disk armature.
9. Ring armature.
10. Drum armature.

Among d-c generators are included:

1. D-c commutating generator.
2. Acyclic generator (unipolar or homopolar).
3. Radial-type acyclic generator.
4. Axial-type acyclic generator.
5. Shunt-wound generator.
6. Series-wound generator.
7. Compound-wound generator.
8. Armature-reaction excited generator.
9. Separately excited generator.
10. Magnetoelectric generator.
11. Double-current generator.

ELECTRIC BATTERIES

An electric battery may be defined as a device which produces electric energy by electrochemical action. Some batteries, storage batteries, provide a convenient means for storing large amounts of energy in a relatively small space. Batteries may be classified as

1. Battery.
2. Galvanic cell.
3. Primary cell.
4. Wet cell.
5. Dry cell.
6. Gas cell.
7. Air cell.
8. One-fluid cell.
9. Two-fluid cell.
10. Daniell cell.
11. Grove cell.
12. Concentration cell.
13. Bichromate cell.
14. Sal ammoniac cell.
15. Caustic soda cell.
16. Weston normal cell.
17. Unsaturated standard cell.
18. Storage cell.

19. Acid storage batteries.
20. Alkaline storage cell.
21. Edison cell.

THERMOPILES

The thermopile converts thermal energy into electric energy. It consists of a group of thermocouples assembled to act jointly as a source of electric energy, and it depends upon the thermoelectric effect (Seebeck effect) for the generation of this energy.

THERMOMAGNETIC GENERATOR

A thermomagnetic generator is one in which an electromotive force is produced in a winding, linking an excited magnetic circuit by varying the reluctance of the magnetic circuit by thermal means.

One method of varying the reluctance is to vary the length of an air gap in the magnetic circuit by thermal expansion and contraction. Another method varies the permeability of part of the magnetic circuit by alternate heating and cooling.

ELECTROSTATIC GENERATORS

An electrostatic generator is a device for the production of electric charges by electrostatic action.

The electrostatic action may be produced in several ways, such as, by friction between solids, between fluids, or between solids and fluids; by induction; or by spraying charges on a moving belt or rotating disk. In each of these methods mechanical energy is converted into electric energy.

MAGNETOSTRICTIVE GENERATOR

A magnetostrictive generator is one in which an electromotive force is produced in a winding, linking a magnetic circuit. The reluctance is varied by periodically varying the mechanical tension or compression on the magnetic circuit.

PIEZOELECTRIC CRYSTALS

According to Cady: "A piezoelectric crystal may be defined as a crystal in which electricity or electric polarity is produced by pressure; or, more briefly, as one that becomes electrified on squeezing; or as one that becomes deformed when in an electric field. The first two definitions express the direct effect, while the third expresses the converse effect."

Cady defines pyroelectricity as "The change with temperature of positive and negative polarization charges on certain portions of crystals belonging to certain classes." He further states that every pyroelectric crystal is also piezoelectric.

EMISSION GENERATOR

An emission generator is one in which an electromotive force is produced by the emission of electrons. One type of emission is known as thermionic emission; another type as photoelectric emission.

CONTACT POTENTIAL (VOLTA EFFECT)

When two dissimilar uncharged metals are placed in contact with each other, one becomes positively charged and the other negatively charged, and a difference of potential, depending on the nature of the metals, is set up between them.

Alternating current can be generated by connecting one end of each of the two dissimilar metals and then varying the capacitance between the free ends. With such an arrangement, mechanical energy is converted into electric energy.

ATMOSPHERIC ELECTRICITY

There exist electric potential gradients in the earth's atmosphere which may be used to produce electric currents.

EARTH CURRENTS

Natural earth currents are currents flowing as a result of natural magnetic disturbances and as a result of electrolytic action in the earth itself.

Different ores under the earth's surface constitute the electrodes and the electrolyte is contained in the earth's moisture.

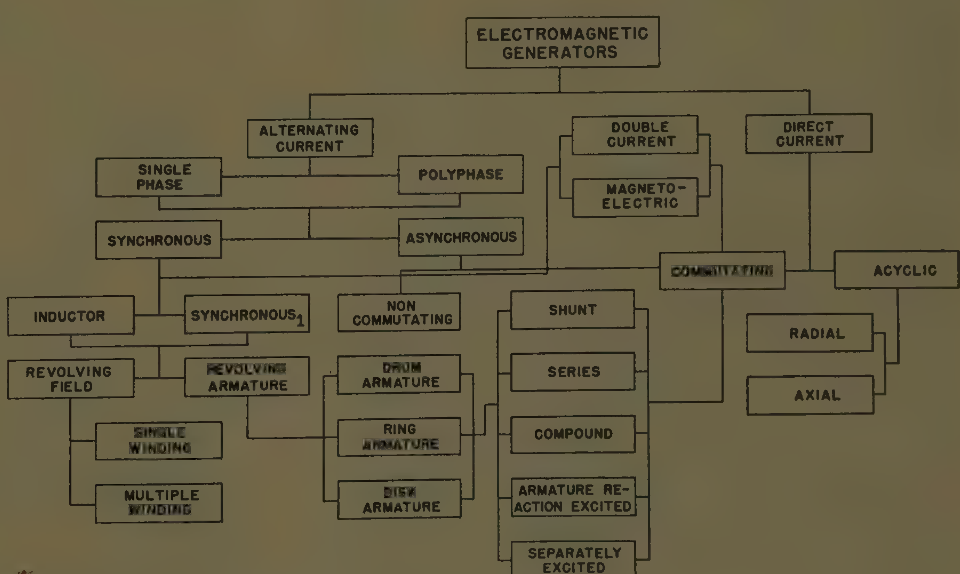

Figure 1. Classification of electromagnetic generators

Variable-Speed Constant-Frequency Alternator

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Frequency is independent of armature speed in an a-c generator described in this student paper. The generator operates on the principle of brush rotation. Several factors to be considered in aircraft generators are mentioned.

CERTAIN commutation difficulties to be expected in a variable-speed constant-frequency alternator of the type described are overcome by a proposed method of using contactors to replace brushes and commutator. A variable speed generator producing constant frequency output would be convenient to use in aircraft. The apparatus described is original so far as is known, and no models have been built.

PRINCIPLE OF OPERATION

Figure 1 shows a 2-pole machine with a d-c type armature rotating at speed N_1. The voltage distribution which might be expected on the commutator, assuming a sinusoidal distribution of flux in the air gap, is indicated using E as the generated voltage that would appear between the brushes when the machine operated as a d-c dynamo and considering the mid voltage between brushes as zero volts. If two brushes were placed in normal d-c position, as shown in the diagram, voltage E would appear between these brushes. It can be seen that rotation of the brushes as a unit would cause an alternating voltage of peak value equal to E to appear between the brushes and varying at a rate of one cycle per revolution of the brushes for a 2-pole machine. By investigating points in between those chosen, it is seen that the wave form would approximate a sine wave. The rms value of the voltage would be $0.707E$. Note that if $N_1=N_2$, where N_2 is the speed of rotation of the brushes, the generator operates as an ordinary alternator, or if $N_2=0$, the generator operates as a d-c dynamo.

If the two opposite brushes are replaced by three brushes placed 120 degrees apart and rotating at speed N_2, as shown in Figure 2, there will be a voltage between brush 1 and brush 2 of $E_{12}=-0.75E$, also $E_{23}=0.75E$ and $E_{31}=0$ for the brush position shown. If this analysis is carried on for a complete revolution of the brushes, it is seen that the voltages between pairs of brushes are alternating at a frequency of one cycle per revolution for a 2-pole machine and that these voltages are displaced in time 120 degrees apart and are therefore 3-phase voltages. The rms value of the voltage between phases would be approximately $0.86 \times 0.707E = 0.61E$.

If N_2 (the speed of revolution of the brushes) is expressed in revolutions per minute, the frequency equals N_2 times the number of poles in the generator divided by 120. It is to be noted that the speed of rotation of the armature (N_1) does not affect the frequency, but that E is directly proportional to N_1, assuming a constant flux per pole. For constant voltage operation the field current must be regulated over rather wide limits if N_1 is to be varied widely.

Since the power required to rotate the brushes is only

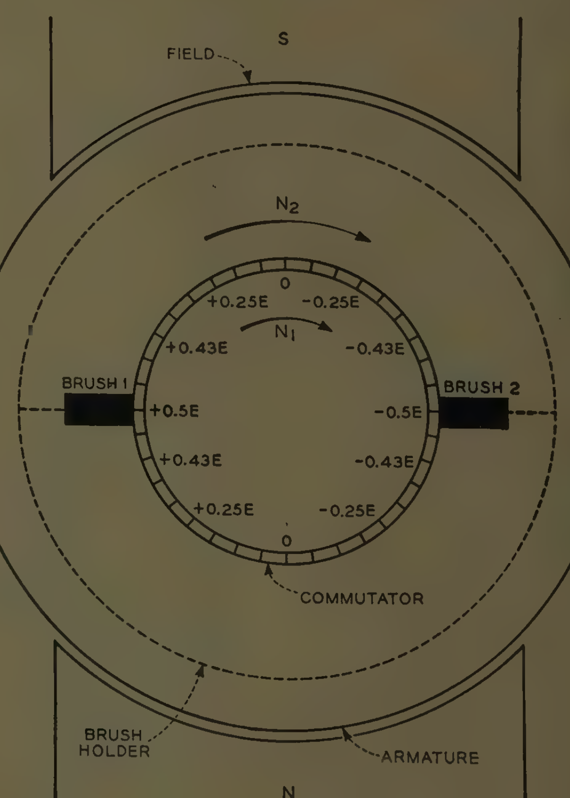

Figure 1. Single-phase variable-speed constant-frequency a-c generator

Essentially full text of a paper presented at a meeting of the AIEE Kansas State College Student Branch, and which has been awarded the national prize for Branch paper for the academic year 1945–46.

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the power required to overcome their friction, it can be supplied by some small auxiliary source, such as a small speed-controlled motor powered from a separate d-c generator.

CONTACTORS

One difficulty that might be expected in operating a generator of this type would be arcing of the brushes, because at times a coil short-circuited by a brush would have maximum induced voltage in it. Brushes and commutator also limit the voltage that could be developed at high altitude. A method of using contactors to replace the brushes is a possible solution to these difficulties.

Suppose a machine is built so that two contactors replace each brush, each contactor alternately contacting successive segments of a commutator without short-circuiting the segments together. Each contactor is connected to one end of resistor. The other ends of the resistors of each pair of contactors are connected together to the power lead to which the replaced brush was connected. The resistors can limit the current from two contactors contacting adjacent commutator segments simultaneously to a reasonable value and not cause excessive losses. Such a device seems to be rather complicated. However, by making the field the rotating part and the armature fixed, a device can be built, as shown in Figure 3.

In Figure 3 fixed generator contactors corresponding to commutator segments are connected to proper points in a closed distributed stator winding. The cam oscillates the moving contactors, so that contact is made to successive fixed contactors with never more than the two adjacent movable contactors, nor less than one, touching the fixed contactors at once. For a 3-phase generator three contactor assemblies of the type illustrated would be necessary for each pair of poles with their respective cams 120 electrical degrees apart. These assemblies would be on a common shaft and the fixed contactors could be shared by all movable contactors.

For grounded neutral operation the neutral connection would have to be supplied by some external device such as a Y-connected induction motor that operates whenever the generator operates, since the generator is mesh connected.

$$(N_1-N_2)\times\frac{P}{120}=f$$

where f is frequency in cycles per second and P the number of poles. N_1 is the rotor speed and N_2 is the cam speed in revolutions per minute.

One type of cam drive mechanism that will hold (N_1-N_2) constant is a constant speed motor driving the cams through a mechanical differential between the shaft of the cams and the rotor shaft. Several other drive mechanisms could be used to accomplish the same results.

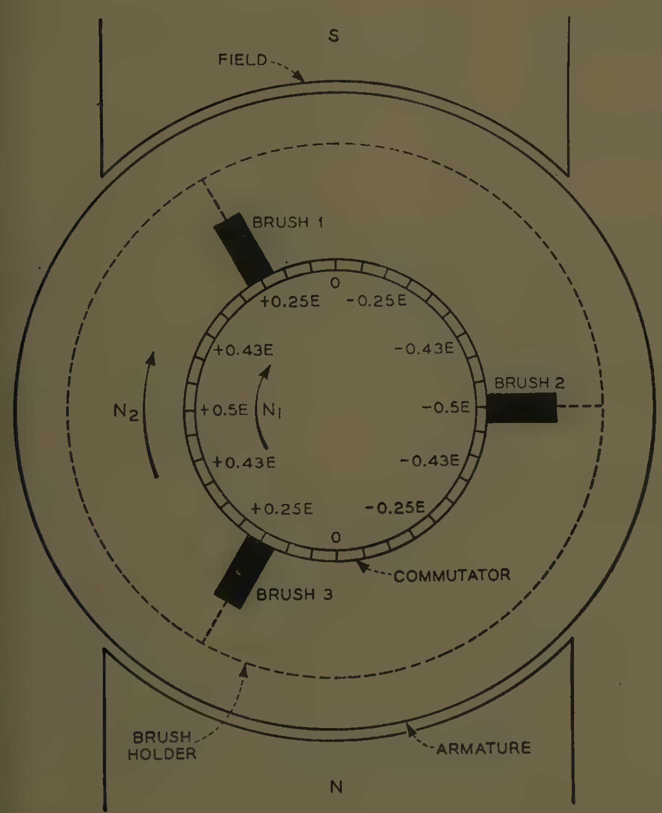

Figure 2. Three-phase variable-speed constant-frequency a-c generator

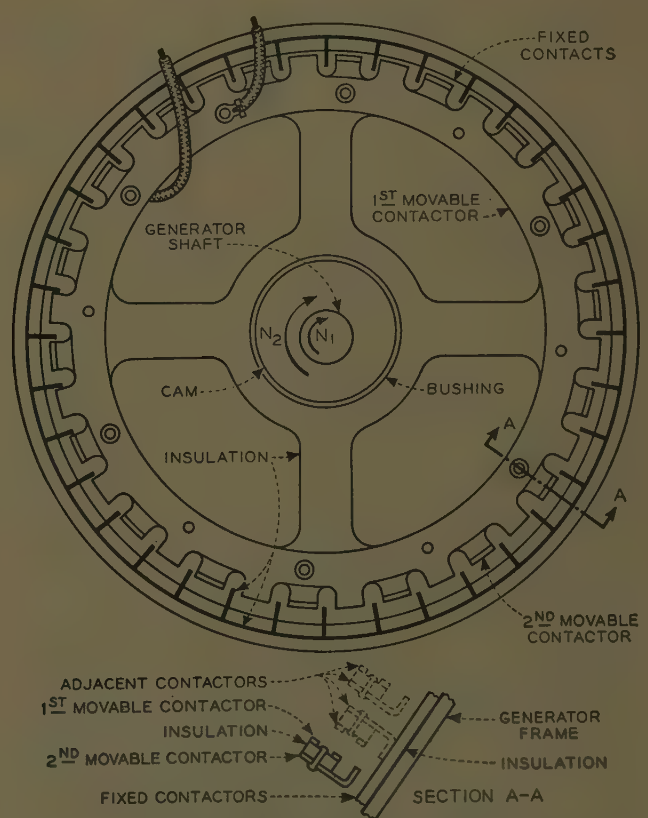

Figure 3. Contactor arrangement to eliminate brushes and commutator

DESIGN FEATURES

There would be little chance for arcing from one fixed contact to another because of the extension of the separating insulation beyond them. The voltage made or broken by the contactors would be a small percentage of the output voltage since at the time each contact is made or broken an adjacent contact is always closed. The resistors in series with the movable contactors can be chosen to limit the current without causing excessive voltage drop under load, providing a sufficient number of fixed contactors are used.

There is a wiping action of the contactors which should help keep them clean. The movable contactors can be connected to an external circuit with flexible leads because they only oscillate and do not rotate. This type of device could be pressurized since the mechanical motion that is required to rotate the cam could be supplied in a pressuretight chamber by a motor or by a shaft extending into the chamber through a pressure seal.

It should be noted that for a constant frequency generator operating over a speed range of 3 to 1 with synchronous speed equal to its mean speed, the cam would turn one half the synchronous speed in a direction opposite to the rotor at the lowest rotor speed. The cam would be stationary when the rotor rotated at synchronous speed and would rotate at one half synchronous speed in the direction of the rotor when the rotor is driven at maximum speed.

PARALLEL OPERATION

Parallel operation of generators of this type would not be difficult. There would need to be a linkage, such as a self-synchronous type, to hold all of the cams of all generators to be paralleled in phase with respect to their rotors as well as at the correct speed.

Once this is done, paralleling would be very simple. As soon as an incoming generator is up to line voltage, it can be connected to the line without causing any serious disturbance, because its voltage is held in proper phase even before it is connected to the line. To equalize the portion of the load taken by one generator in a parallel system, the field currents of the generators can be controlled in a manner similar to that used for parallel d-c systems, since the frequency of each generator is independent of load.

Expedient Power Line Construction

H. L. RORDEN
MEMBER AIEE

Material shortages during World War II imposed limitations on the construction of new transmission facilities and the Bonneville Power Administration conducted tests to determine minimum construction standards. Conductor diameter and spacing and insulation level involving losses, flashovers, safety to personnel working on energized lines, economic loading, and radio interference had to be considered.

DIFFICULTIES in obtaining materials during recent years have made it necessary to economize in the design of new transmission facilities. During war conditions the Bonneville Power Administration undertook such limited means as were possible to determine if economies could be effected in transmission line design without lowering standards of service. One of the first departures from previous practice involved the use of wood poles for transmission of power at 230 kv to relieve a serious bottleneck during the war emergency.

When the materials situation became critical, it became apparent that considerable further saving could be effected if the conductor diameter and spacing, as well as the insulation level, could be reduced. These three items were considered in the light of the hazards that would be involved by their further reduction. The question of conductor separation involved transmission reactance and losses, mid-span flashovers, safety to personnel when working on energized lines, and radio interference. The number of insulators used involved cost and delivery, structure height, and number of structures per mile necessary to maintain required ground clearances at midspan. Conductor diameter involved losses, economic loading, and radio interference.

Selection of the insulation level was based on experience with 115-kv circuits and 230-kv test installations.

Essential substance of paper 47-92, "Radio-Noise Influence of 230-Kv Lines," presented at the AIEE winter meeting, New York, N. Y., January 27-31, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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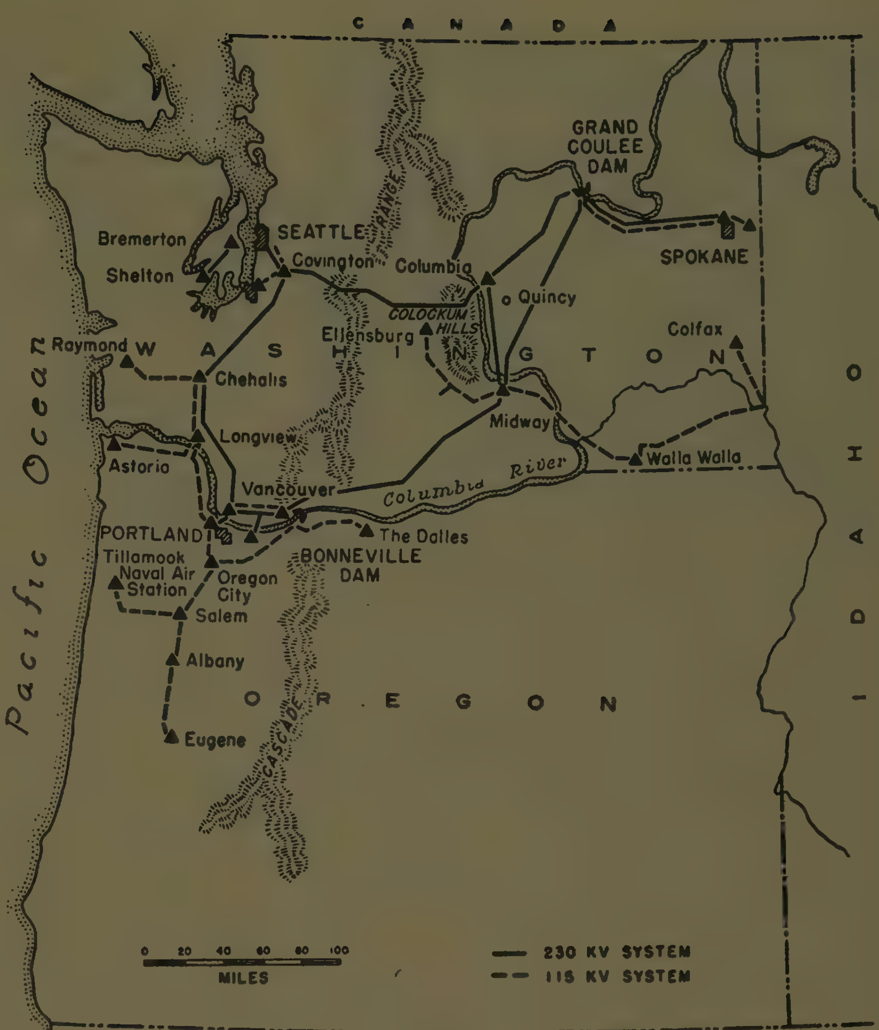


Figure 1. Location of Bonneville-Coulee transmission system (1946)

Most of the lightning hits to the system, which uses ground wires only for station protection, are direct strokes to conductors. So far as is known, these hits always result in flashovers to ground, although occasionally there is no power-follow arc and consequently no outage occurs. Sufficient data have been obtained from protective gaps on the system to conclude that switching surges rarely, if ever, reach three times normal.

Suspension insulators are one of the lesser sources of radio disturbances, irrespective of whether they contain special treatment. The common types of suspension clamps, containing two U bolts which protrude below the nuts, are worse offenders than the insulators. This source of disturbance is not of much consequence on steel towers because of shielding, but is appreciable on wood pole lines.

The questions of conductor diameter and separation are complicated by several variables which should be weighed in proportion to their importance. Reduction of diameter, which also is considered to mean reduction of cross section, increases corona as well as line resistance and reactance. The change in reactance is not of great importance, but increased losses, including a decrease in the firm capacity of the line, must be balanced by the reduction in first cost to be economically justifiable.

Reduction of conductor separation also increases corona losses but involves a decrease in reactance, resulting in a slight increase in the stability limit. The saving in first cost may include width of the right of way but is confined mainly to length of crossarms, which is important if it involves the difference between 1-piece versus spliced arms. Mid-span flashovers are not considered of importance in the selection of conductor separation.

Radio-noise influence was of major concern in the question of conductor diameter and separation. It generally was believed that a reduction of these factors should result in increased noise levels as well as increased losses. It was considered of paramount importance to keep radio-noise influence in the transmissions line areas within an acceptable minimum. Complete data on radio interference from high-voltage lines were not available; and so an investigation was undertaken to determine whether radio noise is a serious item in the design of high-voltage lines.

METHOD OF MEASUREMENT

Measurements of radio-noise influence during this investigation were confined to a Ferris type radio-noise and field-strength meter containing means for calibrating the receiver gain so that the meter reading is proportional to the input. This instrument is equipped with an antenna of such length that the calibrated meter reading is proportional to the microvolts of field strength per half meter. The instrument reads both crest and integrated values, so that readings could be obtained proportional to the radio noise as well as to the average field strength. Frequently throughout the tests, readings were taken at various frequencies to make certain that no radical differences existed from the data obtained at 800 kc which was adopted as the test frequency.

It was found that in order to eliminate radio interference

entirely from ordinary domestic receivers it is necessary to maintain a signal strength of the broadcasting station of at least 40 times that of the interference. Fair reception is possible at a ratio of 25 to 1. These ratios involve variables which may alter them to some degree depending upon local conditions, but it is believed that they represent a fair average. It was considered necessary to maintain lower levels of interference in remote areas than can be tolerated in metropolitan areas because of the greatly reduced signal strength of broadcasting stations in the remote areas. The method of measurement consisted of placing the Ferris meter at predetermined positions with respect to the transmission line, the ground directly beneath the outer conductor taken as the reference with the meter moved away from the line at right angles.

Figure 1 illustrates the general location of the high-voltage transmission system of the Bonneville Power Administration in 1946. The parts of the 230-kv system from Grand Coulee to Spokane, Covington, and Vancouver, all in Washington, all contain parallel circuits. The wood-pole line previously mentioned is the second Coulee-Covington line.

LEVELS WITHIN THE INDUCTION FIELD

The curves of Figure 2 illustrate the radio noise measured at mid-span on a steel-tower line that had been in service for several years (Coulee-Covington number 1). These data illustrate the limited distance through which energy is radiated within the field of direct induction. Normal operating potentials on the Bonneville system range from about 222–244 kv at different points on the system. It is apparent that for fair weather the radio-noise influence is well below the knee of the curve for all distances beyond 100 feet from the outer conductor. At 200 feet the line excitation could be increased to about 260 kv without the increase in noise departing substantially from a linear relation.

Corona loss measurements also were made on this line using commonly available instruments and instrument transformers. In fair weather the losses per 3-phase mile measured as low as 0.6 kw, and in inclement weather that was general throughout the area, as high as 12 kw. A relatively large tolerance probably should be allowed for the low reading, but the high value is believed to be accurate within 10 per cent.

SMALLER CONDUCTOR

Based on the data of Figure 2, a 230-kv line was constructed between Midway and Columbia. Because of its importance to the war emergency, it is a steel-tower line and differs from earlier practice only in the conductor diameter which is one inch. Conductor separation is 27 feet. Although considerable concern was expressed over the use of this conductor because of possible radio noise, early tests with line potentials of 240–243 kv proved that the design constituted good engineering practice as far as radio-noise influence is concerned.

Data show that, even when this line was new, radio noise emanating therefrom was not substantially higher than that of the weathered line of Figure 2, which uses a larger conductor. Although there is somewhat greater conductor height for this line, other data show that this difference apparently is not of great importance. Of particular interest was the lower noise level measured under the center conductor than that measured under the outer conductor. Tests showed rapid attenuation of the induction field, the noise influence falling to about three per cent of its maximum measured value in 300 feet.

The Midway-Columbia line, containing the 1-inch conductor, has been used for repeated tests of radio-noise influence in the interest of design of future lines. Data were obtained on this line at approximately monthly intervals from the time the line was energized and extending over a period of approximately 11 months. The purpose of the test was to determine how long it takes for the corona level to become stable and constant. Irregularities were expected, but the data differ considerably from those which were anticipated. The results may be influenced by weather changes between winter and summer. However, they are of interest because of the extreme reduction in the measured noise level that occurred early during the tests and the gradual recovery to a more or less uniform average that followed.

Data were obtained on one of several continuous runs made to observe hourly variations in radio interference. Differences occurred in noise level due to a storm estimated to be about 15 miles distant in a straight line from the test area, but over lines of the 230-kv system, some 25 to 30 miles distant along the transmission line. It seems probable that electrostatic influence was projected along the transmission line since the noise level decreased in the usual manner when the meter was

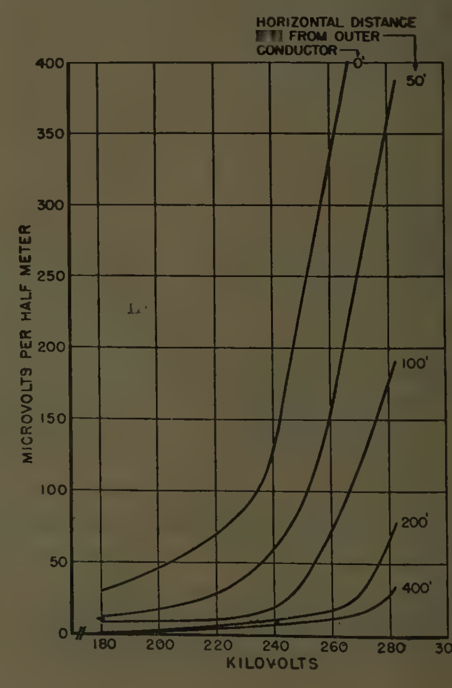


Figure 2. Corona radiation on Covington-Grand Coulee line number 1

Conductor: Aluminum conductor steel reinforced 1.108-inch outside diameter 26 strands aluminum, 7 steel, 27-foot separation, 41-foot height
Weather: Fair, temperature 22–38 degrees Fahrenheit
Test frequency: 800 kc

placed at increasing distances from the line. The background noise level at the test area did not increase.

DECREASED CONDUCTOR SEPARATION

Four consecutive towers on the Midway-Columbia line were selected for determining the effect of reduced conductor separation. The outer conductors were drawn toward the towers, as is illustrated in Figure 3, so that the conductor separation for three spans was approximately 18 feet. The rest of the line remained at its normal 27-foot spacing.

Prior to the tests some predictions indicated that the radio noise due to corona would increase with decreased conductor spacing. This thought probably was due to the well-known fact that corona power loss increases with decrease in spacing, and it was believed that the radio-noise influence would be porportional to the losses. This theory was proved to be in error, the tests indicating a reduction of radio noise with the decreased spacing. These tests have been repeated on several occasions in order to eliminate the possibility of error. The noise level in all instances, including both the 27- and 18-foot areas, was considerably lower opposite the towers than at mid-span. Radio-noise influence measured at towers where conductor separation is 27 feet is considerably higher than it is at towers within the 18-foot area. Directly under the towers where the conductors hang at their normal 27-foot separation, corona is hardly audible in fair weather. At the towers where the conductors have been drawn in to 18-foot separation, there is considerable audible corona at all times.

It is apparent from the foregoing results that the radiated radio-noise influence is not proportional to corona. It is also apparent that the energy radiated into space is reduced by drawing the conductors toward the grounded steel towers, although the electrostatic field between the conductor and the grounded steel is increased very considerably.

ANALYTICAL VERIFICATION

Although these data are contrary to commonly advanced theory, they are not difficult to understand from hindsight analysis. C. M. Sorvaag of the Bonneville staff has advanced the following explanation for this phenomenon.

It is a well-known fact in the field of radio communications that an open 2-wire radio-frequency transmission line will radiate an amount of radio-frequency energy depending upon line spacing, wave length, power transmitted, and other circuit conditions. With a properly terminated balanced open 2-wire radio-frequency transmission line under conditions of fixed frequency and power, the amount of radio-frequency energy radiated will be inversely proportional to the square of the conductor spacing. At decreasing values of conductor spacing, the radiation will decrease and more energy will be propagated down the line. Practically zero radiation

Figure 3. Tower 202 of Midway-Columbia line with outer conductors drawn in to 18-foot separation from center conductor; tower equipped with weather recording instruments

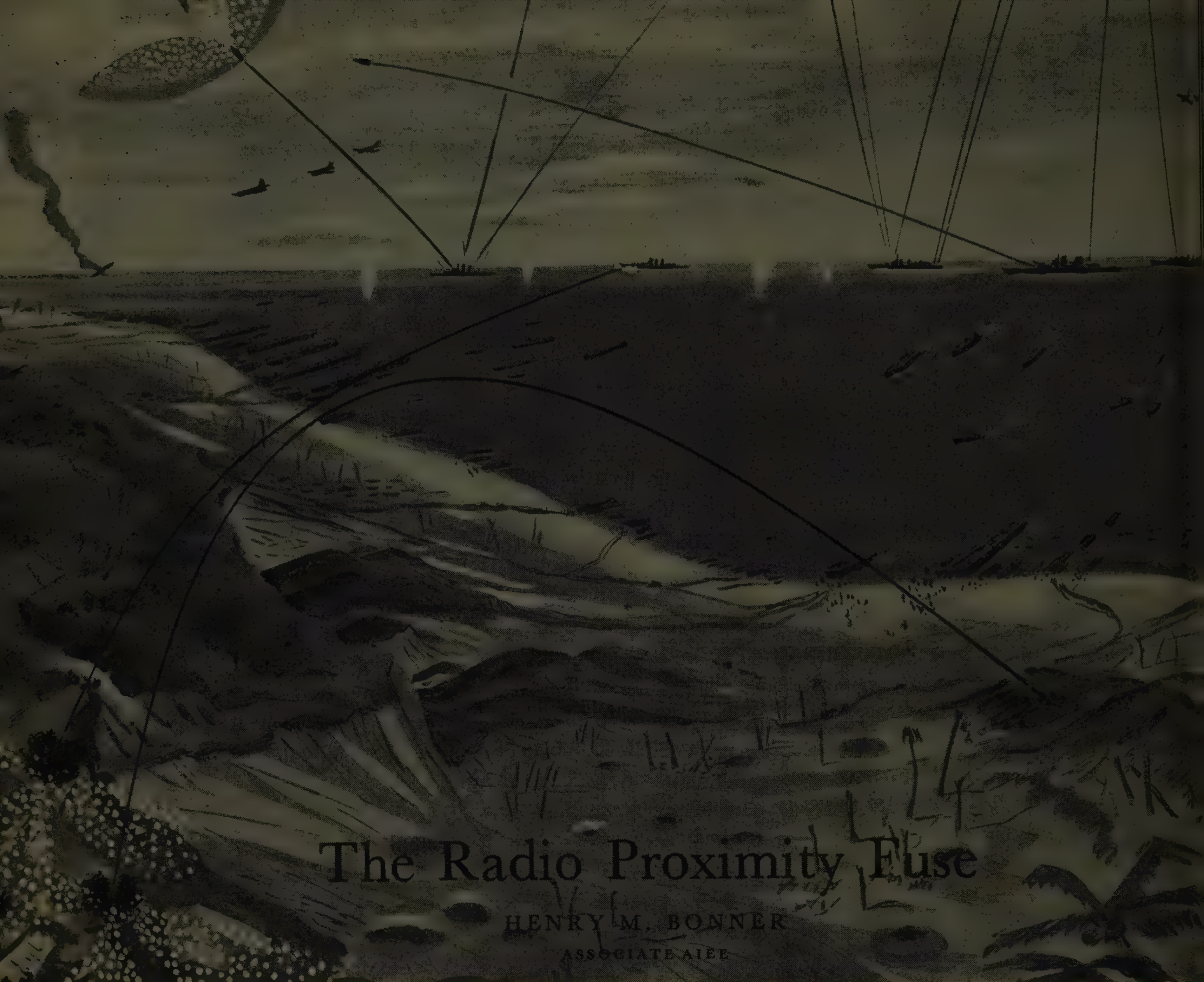
would exist when the 2-wire line is resolved into a coaxial type of transmission line, and all of the radio-frequency energy is transmitted down the line except for line losses.

So far as radiated radio noise is concerned, we consider for the sake of simplicity that only two wires of the transmission line are affected, and that the corona will be a point discharge, or simply a random radio-frequency generator between the two conductors. In this case a portion of the radio-frequency component of the corona will be radiated and the remaining radio-frequency energy will be propagated down the transmission line in both directions.

This investigation has resulted in design of 230-kv H-frame wood-pole lines including 11 insulator units, 18-foot conductor separation, and 1-inch diameter conductor. Radio-noise influence ordinarily is not considered to be a limiting factor in high-voltage transmission line design. Suspension insulators are not responsible for radio-noise levels emanating from high-voltage lines, even though the line-end unit may be stressed to the corona limit. Static discharges can be severe offenders, and hardware is sometimes responsible. Selection of conductor size should be based on losses and system characteristics rather than on radio-noise levels. Safety to personnel working on energized lines rather than radio noise or mid-span flashovers is considered to be the limiting factor in conductor separation.

The Radio Proximity Fuse

HENRY M. BONNER
ASSOCIATE AIEE



Courtesy Sylvania

Figure 1. The VT fuse as used for antiaircraft fire and against protected enemy personnel

The fan-shaped area indicates the effective field for fuse action; the dotted areas indicate shrapnel bursts. The proximity field was designed to coincide with the burst patterns

One of the most closely guarded technical secrets of World War II, the proximity fuse was developed to counteract the natural defenses of both the airplane and the infantry. This review of the conception, the construction, and use of the fuse reveals how almost 100 per cent accuracy was built into the artillery of the Allies in World War II.

THE THEME has been expanded that for every weapon there exists a counterweapon, and this fact has been as true in the recent war as in any other. In history, each time a more deadly weapon has been introduced in warfare, another weapon, or a defense, has been developed to nullify its initial advantage. Before the invention of gunpowder, the shield and the suit of armor were partial defenses against the spear and the long bow; but these finally were pierced by the explosively propelled bullet, and the fortifications of the medieval castle crumbled at the impact of the cannon.

Henry M. Bonner, formerly with the Eastman Kodak Company, Rochester, N. Y., is now a graduate student at Columbia University, New York, N. Y.

A weapon new to the first World War was the airplane, opposed by other airplanes and by antiaircraft fire from the ground. In World War II the airplane, although still bound to the earth's atmosphere, was brought, from our present point of view, to a high degree of perfection and of effectiveness. That effectiveness, however, was limited drastically by the development of more efficient techniques of antiaircraft defense, including radar tracking of the target and the proximity fuses.

PROXIMITY FUSE

The proximity fuse, as a method of projectile control, also has limited the usefulness as a defense of a simple hole

in the ground, the much publicized foxhole of World War II. Both the airplane and the bank of earth, one an offensive weapon, the other a defensive one, have been counteracted by an idea made practical by Anglo-American scientists and American industry. The idea demanded the building of a radio transmitter and receiver, small enough to be mounted, along with its energizer or battery, in the front end of a high-explosive projectile, and strong enough to withstand the shock of being fired from a gun at 20,000 times the acceleration of gravity.

LIMITATIONS OF A MECHANICAL FUSE

In antiaircraft use the limitations of a mechanical time fuse, which must be set before firing and which must employ absolutely uniform powder charges, are readily evident. Even though a device had been developed to set the mechanical time fuses automatically on the basis of information supplied by the gun director, the positive action of a proximity field fuse had the advantage of eliminating the necessity of setting the fuse and made its action independent of gun charge or inaccuracies in the mechanical timing mechanism.

For howitzer use, proper adjustment of timed fire requires the firing of about 15 experimental rounds to obtain air and ground bursts, so that the fuse setting can be determined. Valuable time and ammunition are wasted with this procedure, and the enemy is warned to retire from the target area before the fire becomes effective.

Proximity fuses in this application have made foxholes and trenches untenable and have destroyed the protection of revetments. With the proximity fuse, uniform bursts 20 or 30 feet above the ground can scatter a deadly hail of fragments over the surrounding terrain from the first round. The fuses thus have increased the efficacy of missiles from 10 to 20 times. If one fighter can punch ten per cent harder than his opponent the fight is won; if he can punch ten times as hard. . . .

GERMAN RESEARCH

Enemy interest in a proximity fuse was shown in the 1942 spy trials which disclosed that the Nazis were trying to find out whether the Allies possessed such a device. Only too well aware of the potentialities of a proximity fuse, the Germans themselves had started work on the idea as early as 1930; but no design ever was put into quantity production. A multiplicity of fuse types and of groups working on them, combined with a lack of cooperation between the respective groups and between the civilian groups and the military, led to the failure of their program. The Germans were working on acoustic, electrostatic, radio, and 30 other types of fuses, which incidentally were considered only for rockets and bombs. Apparently no German was fool enough to consider firing radio tubes from a gun. For this combination of reasons the Germans were well behind the Allies in their program.

ANGLO-AMERICAN APPROACH

In the United States, the National Defense Research Council, later the Office of Scientific Research and Development (OSRD) was requested to investigate the possibilities of making a proximity fuse, and the attack was conducted along two independent lines with the purpose of simplifying the question of supply and of administration. The Navy sponsored the development and procurement for both services, and for the British, of fuses for howitzer, antiaircraft, and heavy rifle use (75 to 240 millimeters—anything between about 3 and 10 inches); the Army undertook the same problem for all bomb and rocket type fuses. These fuses were known as *VT* fuses by the Navy and *POZIT* fuses by the Army.

Two approaches were considered and developed successfully, although only the second of these actually was put into large scale production or use:

1. Pulse fuse.
2. Radio or proximity field fuse.

National Bureau of Standards photo

Figure 2. Compactness of the tubes manufactured for the proximity fuse (right) as contrasted with the conventional radio tube (left)

The first of these fuses is controlled remotely from the ground by radio. When shell and target are observed to be coincident on a radar screen, the fuse is activated and the explosive detonated. The second and most important fuse type radiates a continuous-wave radio signal which upon reflection detonates the shell. The action is thus completely automatic.

Several types of proximity fuses actually were considered and worked upon. These were:

1. Photoelectric (actually put into limited production for rocket fuses, but subject to certain obvious disadvantages, such as variations in lighting conditions).
2. Infrared.
3. Acoustic.
4. Electrostatic (this was the most successful German approach, and some models actually were put into limited production).
5. Radio, depending upon discontinuities of conductivity, dielectric characteristics, and so forth.

The last of these is the one successfully developed and put into mass production in the United States for both British and American use.

DESIGN PROBLEMS

When it is remembered that these fuses must withstand an acceleration of 20,000g in being fired from a gun, the extreme design problems, especially for the miniature radio tubes used, can be understood. At such an acceleration a penny would weigh 130 pounds on a spring balance; an ounce of glass and wire would weigh more than half a ton, and ordinarily a radio tube will break at 10 to 50g. In order to construct a tube that would overcome these obstacles, a major redesign was required, for the weight of the tube elements could be reduced by a factor of only about ten. Under these conditions, the weight of a soldered joint becomes very important.

As has been explained, the Army undertook development of bomb and rocket type fuses, which in general contend with a different set of conditions. As the accelerations encountered are not nearly so great, different mechanical designs resulted; and, furthermore, the high altitudes and low temperatures encountered by high-flying bombers and fighters led to the use of wind-driven generators rather than energizers or batteries of the type used for gun fuses.

All of these fuses, moreover, had to be mechanically interchangeable with the current types.

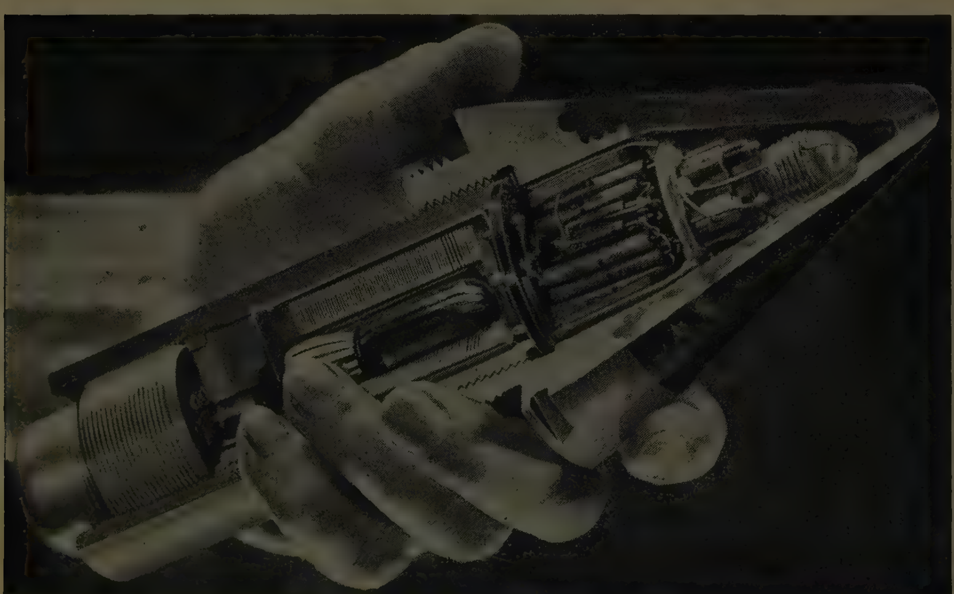
PRODUCTION

Prime contractors for the manufacture of these fuses under Navy contract (for gun use) included, besides The Eastman Kodak Company, which is the only company still in this field, The Crosley Corporation, The Sylvania Electric Company, The Radio Corporation of America, and McQuay-Norris Manufacturing Company. The important energizer suppliers were the National Carbon Company, Eastman Kodak Company (working from National Carbon designs), and Hoover Company.

At the end of the war, The Sylvania Electric Company, which produced about 95 per cent of the tubes used at these accelerations, was producing about 500,000 per day. Before the war, only about 600,000 tubes per day of all kinds were made by all companies in the United States.

Prices also underwent a noteworthy revolution. The first pilot models of these fuses in 1942 and 1943 cost about \$40 a piece, exclusive of Government-furnished material, such as tubes and heavy steel parts. Mass production methods cut this cost to \$5 or \$6 a piece (about \$15—\$18 including Government-furnished material) and at peak production the various companies produced a total of more than 250,000 fuses per week. As this was a completely new manufacturing problem, contracts were let on a cost-plus basis.

Production was speeded greatly by being broken down into simple easily performed operations, and the complete unit thus was built up from a number of simpler subassemblies. All the resistors and capac-



National Carbon photo

Figure 3. Complete Mark 53 proximity fuse assembly

From the nose down are shown: the radio transmitter and receiver, the batteries, space for the safety switches, and the detonator

itors in the amplifier circuit, for example, first were assembled in a flat form and then wrapped around the rubber sock which contained the tubes (this procedure was initiated at Eastman Kodak and later adopted by several other companies). Waste was reduced to a minimum by the careful screening of rejects, for in the bundle stage (before addition of the radio-frequency section) and in the prepot stage (before potting) the units could be repaired in many instances. After several rejections, however, wear and tear, plus the weakening and breakage of wires, especially the brittle capacitor leads, made salvage impractical, and the units were destroyed.

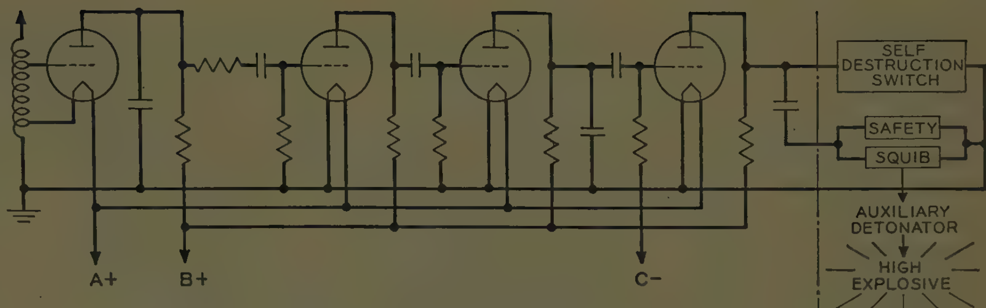


Figure 4. Hartley type oscillator circuit as it might be used in a proximity fuse circuit

SECURITY

Security was, and is, strict on this project. During the war, the very existence of such a device as the proximity fuse had to be kept secret. For this reason, all personnel were investigated carefully, and few people were allowed to know what really was being made, although some of the foremen and supervisors knew or guessed a great deal, as did a few of the workers. Code names were adopted in order to obscure the function of many classified parts. Tubes were called "glass"; capacitors, "tubulars"; and certain terms, such as "oscillation," were not used. Rumors occasionally leaked out, and at various times the project was thought to be making parts for *B-29*'s, dental X-ray equipment, and the like, but secrecy was well kept.

As this was a secret weapon, a most important restriction on the use of *VT* or proximity fuses was the prohibition against using them when duds might be recoverable. This meant, until after the Normandy invasion, that they could be fired only on the high seas, and, as a further precaution, for some time mixtures of mechanical and proximity fuses were used in order to screen the improved performance of the latter and keep its very existence secret. Each and every fuse had to be accounted for under all circumstances, and this made handling difficult. According to one artillery officer, a group in the Battle of the Bulge spent two hours scuffing through the snow hunting for two fuses which finally were brought in by a French peasant woman who had been attracted by the peculiar conduct of the men.

THE RADIO PROXIMITY FUSE IN ACTION

Initial use of the radio proximity fuse in battle came January 5, 1943, when the cruiser *Helena* in the Pacific shot down an attacking airplane with two salvos from two twin-mount 5-inch guns. Wholesale use of the fuses was made by the destroyers *Hadley* and *Evans* in May 1945, off Okinawa. At 7 a. m. a wave of suicide airplanes was spotted; at 7:03 a. m. the first airplane was shot down. Over 150 "kamikaze" airplanes attacked these two ships, and all the attackers were shot down. The *Evans* was struck four times by blazing airplanes or parts; and in one attack on the *Hadley* staged by ten airplanes simultaneously, parts of two hit the deck. Thus, this attack of 150 suicide airplanes resulted in the suicide of all 150 with only six blazing airplanes or parts of airplanes penetrating the screen of *VT*-fused fire. According to an official report, ". . . the horizon from the east to the northwest was full of burning planes. There were too many to count. . ."

Christmas Day 1944 was set as the date of presentation of the *VT* fuse to the Germans, but this date was forced ahead one week by the German counterattack and advance through the Ardennes and by the resultant Battle of the Bulge. After a *VT* fuse barrage, according to an artillery officer who was in the Battle of the Bulge, the forest into which the Allied troops advanced looked as though it had been topped by the sweep of a giant scythe. Tree trunks were shattered and torn; almost every tree was severed about 40 feet from the ground.

Against the robot bombs also, the *VT* fuses proved of great worth. Of 104 *V-1* robot bombs fired in one day, only 4 reached their target, London. Sixty-eight were shot down by *VT*-fused antiaircraft fire; 14 were downed by the Royal Air Forces; 2 hit barrage balloons or their cables; and 16 suffered mechanical failure in flight.

During the later stages of the Pacific war, one third of all bombs dropped from carrier based airplanes were *VT* fused. Iwo Jima had the first pre-*D*-day bombardment with proximity-fused bombs in February 1945 from airplanes based upon Saipan. The antiaircraft fire after such a saturation bombing was unusually light. *VT*-fused bombs were most effective against antiaircraft personnel and demoralized the gun crews. In April 1945, the 15th Air Force from *B-24*'s at 25,000 feet dropped *VT*-fused bombs on flak positions in Northern Italy. All enemy batteries ceased firing, and the main body of the air group followed through the corridor unmolested. There was no antiaircraft fire for $2^1/_2$ hours. The 9th, 12th, and 15th Air Forces used *VT*-fused incendiary bombs with devastating effect.

OFFICIAL TESTIMONIALS

Secretary of the Navy James Forrestal stated that the proximity fuse protected our surface ships and greatly reduced the cost in both men and ships of the Pacific war. General George Patton said, "The new shell with the funny fuse is devastating. The other night we caught a German battalion which was trying to get across the Saar river with a battalion concentration and killed by actual count 702. I think when all Armies get this shell we shall have to devise some new method of warfare. I am glad that you all thought of it first. . ."

VT FUSE CONSTRUCTION

The field of sensitivity of these *VT* or radio proximity fuses was designed to coincide as closely as possible with the burst pattern of the shell, in order that maximum effectiveness should be obtained. The amplifier is peaked at the Doppler frequency to reduce noise. Five safety devices are included for protection of our personnel.

In the proximity fuse a continuous-wave signal is transmitted and detection of the target is effected by the frequency shift of the reflected signal, a shift caused by the relative motion of the fuse and the object being detected.

As projectile and target are in relative motion, the proximity fuse can be considered as stationary, with the target approaching it at their relative velocity, v. The target then will intercept v/λ extra waves each second and, therefore, will receive a signal of apparent frequency

$$f_a = f_0 + v/\lambda$$

or, since

$$\lambda = c/f$$
$$f_a = f_0(1 + v/c)$$

To find the apparent frequency of the reflected signal finally received at the fuse, consider the target as stationary and the fuse as in motion. The reflected signal finally received at the fuse, therefore, will have a frequency

$$f_r = f_a(1 + v/c)$$

or

$$f_r = f_0(1 + 2v/c)$$

The transmitting antenna is also the receiving antenna, and the transmitting oscillator doubles as an amplifier and autodyne detector. The beat note, or difference between the local oscillator frequency and the received frequency, will be $f = 2f_0(v/c)$. The radio-frequency components of the combined signals are by-passed to ground, and the Δf then is amplified. Selective filter and feed-back circuits in the amplifier peak it at the Doppler frequency and adapt its sensitivity to its purpose.

Essentially, therefore, the *VT* or radio proximity fuse

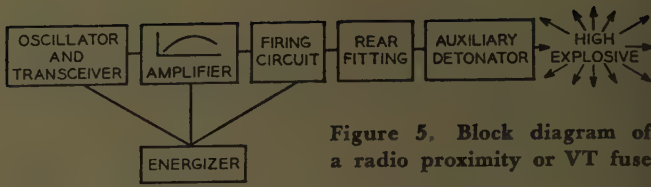


Figure 5. Block diagram of a radio proximity or VT fuse

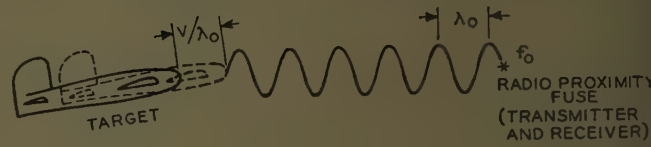


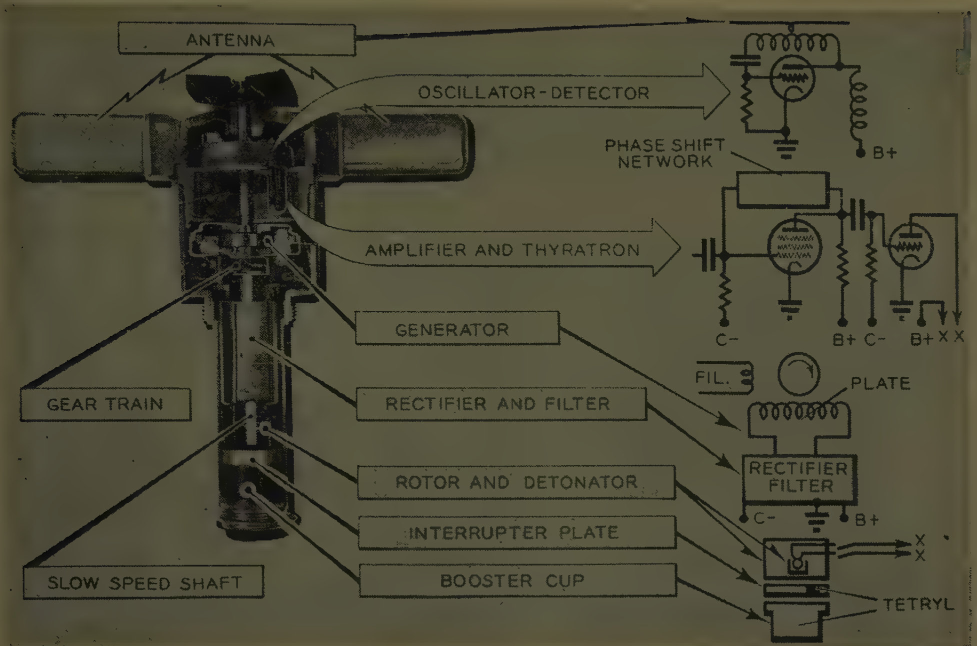
Figure 6. Doppler effect for moving transmitter

$f_a = f_0 + v/\lambda$
f_0 = frequency at origin (fuse)
f_a = apparent frequency at target
V = relative velocity of target and fuse
λ = original wave length of signal
C = velocity of light

consists of a very compact oscillator which radiates a continuous signal to the sides of the projectile in a pattern approximating that of the shell burst; and this signal is reflected from any body in its field. The target need not even be a good conductor, as the induced current responsible for reflection can be a displacement current. Any discontinuity of conductivity, dielectric constant, or permeability can cause reflection. The reflected signal is picked up by the transmitting antenna, and interference between this reflected signal and the original signal gives a beat note. This signal, appearing across the load resistor in the plate circuit of the oscillator, which doubles as an autodyne detector, is filtered and amplified. The amplified signal then is applied to the grid of a miniature thyratron, which fires upon application of a strong enough signal, thus discharging a capacitor through the explosive squib. The squib sets off the auxiliary detonator, and that in turn sets off the high explosive charge. The whole fuse, consisting of antenna, oscillator, amplifier, thyratron, and firing capacitor is potted with a microcrystalline wax for moisture protection and for mechanical support.

THE ENERGIZER

The energizer, or battery, used in conjunction with the radio proximity fuse was originally a dry battery, and the voltages were applied to the fuse at setback or firing of the gun by inertia switches, which consisted of a tight coil of soft wire with a weighted end that sagged into permanent contact with a metal cup at setback. The shelf-life of these dry cells was limited to about six months, and the present type of battery consequently was evolved with an acid-containing ampule which breaks at setback, thus activating the battery. One of the great problems in designing this energizer was the elimination of random potential fluctuations, otherwise known as noise, during the flight of the projectile.



National Bureau of Standards photo

Figure 7. A cutaway view of the generator-powered bomb use with a schematic circuit diagram of the primary subassemblies

explosive charge from going off until it actually is fired from a gun. Even dropping the projectile and releasing the electrolyte cannot actuate the fuse. The fifth precaution prevents muzzle bursts which could destroy gun and crew, or prematures which might scatter fragments among an army's own troops when the projectiles are fired over their heads at the enemy.

On the bomb fuses an auxiliary propeller and gear train could be clipped to the fuse which would release the fuse propeller after a predetermined amount of air travel. This allowed the fused bombs to be dropped safely through deep formations of bombers.

Generator-powered fuses also were used on rockets fired from airplanes, thus providing them with the equivalent of heavy caliber guns.

For bomb fuses a small wind-driven propeller was used to drive a generator which supplied the necessary electric power for the fuse. This finally was made into a more compact and more vibration-free turbogenerator rotating at 50,000 rpm.

SAFETY DEVICES

Five precautions were built into the complete assembly of the proximity fuse in order to avoid danger to firing personnel and friendly troops. These were:

1. The energizer is not operative until setback breaks the acid-containing ampule, and spin from the rifling in the gun barrel is required to distribute this electrolyte through the battery.

2. A mercury switch short-circuits the squib until the unit is spun at high rate. (In normal operation a charged capacitor is discharged through the squib to detonate the shell.)

3. A mechanical spin switch is incorporated to short-circuit this capacitor unless the unit is spinning. This gives protection until the unit is fired from the gun. When the rate of spin falls below a preset value after a charge has built up on the capacitor during flight, this switch discharges it through the squib, thus insuring self-destruction of the unit.

4. An out-of-line powder train is incorporated between the squib and the charge in the auxiliary detonator. This powder train is aligned by the spinning action.

5. A time delay is incorporated in the charging circuit of the capacitor which fires the squib to prevent the shell from detonating until it is well away from the gun and from firing personnel and friendly troops.

The first four precautions, which function by preventing activation of the energizer, by short-circuiting the explosive squib, by not allowing the firing capacitor to build up its charge, and by preventing the squib from firing the auxiliary detonator, keep the projectiles high-

IMPORTANCE OF THE PROXIMITY FUSE IN WORLD WAR II

Admittedly, the atomic bomb is the world's outstanding weapon, highlighting the need for the international rule of law and order; but radar and the proximity fuse had as important a role in World War II as any other single project. Although the Manhattan Project, the release of atomic energy, will have a much greater effect on the history of mankind and on the terms of peace, nevertheless, Project *A*, proximity field fuses for bombs and shells, affected more greatly the outcome of World War II.

These fuses in themselves have served to increase the effectiveness of antiaircraft fire about five times. Early in the war, it took about 1,000 shells to bring down an airplane; with mechanical time fuses and radar fire control about 500; with *VT* fuses about 85–100. Proximity fuses helped to save London from the buzz bomb, helped to turn the tide at the Battle of the Bulge, helped to oust the Japanese from his foxhole, helped to make the "kamikaze" impotent.

Howitzer bursts at tree-top height, or just above the ground, drove the stunned Germans from the forests of Bastogne. *VT*-fused antiaircraft fire, with the aid of automatic radar tracking, brought down more than 80 per cent of the robot bombs over England and most of the Japanese "kamikaze" airplanes over the Pacific. *VT*-fused rockets also were used effectively against aircraft and ground installations.

Voltage-Regulated Power Supplies

LEONARD MAUTNER

Basic design considerations are analyzed for power supplies with unusually low internal impedance and low output ripple, an aspect of the larger subject of voltage-regulated supplies which the author believes has been lacking clarification.

THOUGH design of conventional voltage-regulated supplies has been covered fairly extensively elsewhere [1,2,3,4,5] certain theoretical design considerations have not been treated adequately. In particular, for some television applications, power supplies with unusually low internal impedance and low output ripple are needed, and this article proposes to set forth some basic design considerations. The relation of the work reported in the references to this article will be discussed toward the end of this treatment.

Inasmuch as the ultimate performance of a well-designed supply may depend on both the adequacy of circuit treatment as well as construction details, these several aspects will be treated separately as follows:

1. Theoretical circuit analysis.
2. Practical design considerations.
3. Typical circuits and performance data.

THEORETICAL CIRCUIT ANALYSIS

The basic circuit for the series type regulator in common use is that shown in Figure 1. In this configuration a rectifier is used to provide a source of direct potential E_0 from the main source of a-c power. It is usual to expect the value of E_0 to vary if either the line voltage or the load current varies. In addition, the direct voltage E_0 has an appreciable harmonic content from the main a-c source; in the case of 60-cycle supplies this consists largely of 120 cycles-per-second ripple. Through use of the regulator, these undesirable effects are minimized.

The action of the regulator is basically this: a fraction β of the output voltage E_2 is compared with a standard reference voltage E_R, the difference voltage being amplified through an amplifier of gain G; the amplified difference voltage E_1 then is applied to the grid of the series tube so that it causes the series tube to oppose the original output voltage variation. This it does by altering its effective plate resistance. In essence then, a feed-back amplifier is used to keep the output voltage as nearly stable as the reference voltage, regardless of the cause of the possible variation. The higher the loop gain in the feed-back chain, the more nearly the stability of the voltage E_2 will approach that of the reference standard. Specifically, if the feed-back amplifier is a d-c amplifier, then the magnitude of E_2 also can be maintained at a fixed ratio of the magnitude of the reference voltage.

To evaluate the results mathematically, it will be useful to consider the basic circuit in some detail. The series tube in Figure 1 can be considered a cathode follower; consequently, the voltage-regulating action of a cathode follower can be considered fundamental to the analysis. Assuming, for the moment, that the amplifier of Figure 1 has a gain of unity, the incremental plate current di_p for the cathode follower can be evaluated from Taylor's series as

$$di_p=\frac{\partial i_p}{\partial e_g}de_g+\frac{\partial i_p}{\partial e_p}de_p+\ldots \qquad (1)$$

Now

$$de_g=dE_1-R_Ldi_p$$

$$de_p=dE_0-R_Ldi_p \qquad (2)$$

If equations 1 and 2 are combined and terms higher than the first order are neglected,

$$di_p=g_m(dE_1-R_Ldi_p)+\frac{1}{r_p}(dE_0-R_Ldi_p)$$

$$di_p\left(1+g_mR_L+\frac{R_L}{r_p}\right)=g_mdE_1+\frac{dE_0}{r_p}$$

And

$$di_p=\frac{\mu dE_1+dE_0}{r_p\left(1+g_mR_L+\frac{R_L}{r_p}\right)}=\frac{\mu dE_1+dE_0}{r_p+R_L(\mu+1)}$$

But

$$dE_2=R_Ldi_p$$

Thus

$$dE_2=\frac{\mu dE_1+dE_0}{\mu+1+\frac{r_p}{R_L}} \qquad (3)$$

Equation 3 makes possible prediction of the amount of variation in E_0 that is transmitted to the cathode circuit. If $dE_1=0$, then

$$dE_2=\frac{dE_0}{\mu+1+\frac{r_p}{R_L}}=\frac{R_LdE_0}{R_L(\mu+1)+r_p}$$

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The author wishes to express appreciation to Robert M. Walker and Doctor James L. Lawson of the Radiation Laboratory, Massachusetts Institute of Technology, for permission to use unpublished material from their notes. In addition, thanks are due to J. H. Mulligan, Jr., and E. E. St. John of the Allen B. Du Mont Laboratories for their suggested circuit designs and criticism.

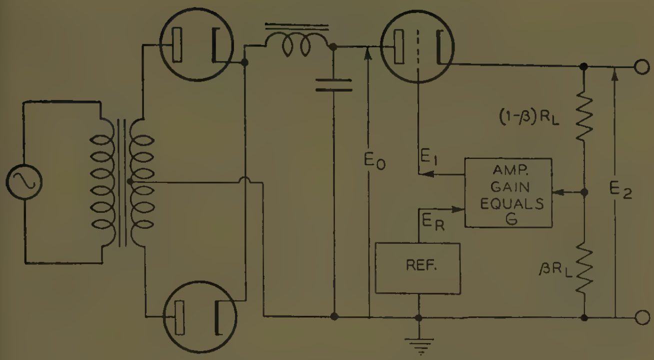

Figure 1. Voltage regulator—basic series type

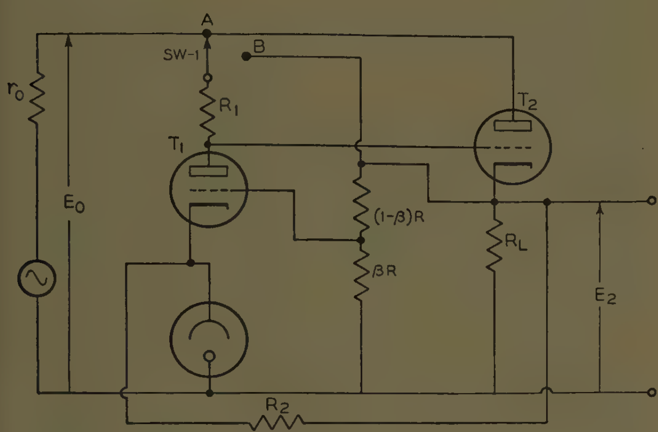

Figure 2. Voltage regulator—diagram of basic series type

But the amount of variation predicted from a divider consisting of r_p and R_L would be

$$dE_2' = \frac{R_L dE_0}{R_L + r_p} \tag{4}$$

The ratio of dE_2' to dE_2 then is

$$\frac{dE_2'}{dE_2} = \frac{R_L dE_0}{R_L + r_p} \cdot \frac{R_L(\mu+1) + r_p}{R_L dE_0}$$

$$= \frac{R_L(\mu+1) + r_p}{R_L + r_p}$$

If

$\mu \gg 1$,

$$\frac{dE_2'}{dE_2} = \frac{1 + g_m R_L}{1 + \frac{R_L}{r_p}} \tag{5}$$

Thus a cathode follower tends to attenuate variations in plate potential, as observed at the cathode. In a typical case, if $g_m = 5{,}000$ micromhos, and $r_p = 8{,}000$ ohms, then

$$\frac{dE_2'}{dE_2} = \frac{26}{1.675} = 15.5$$

Consequently, in this case only about 6.5 per cent of the expected variation will be apparent at the cathode. This reduction in plate supply variation is often helpful in the design of cathode followers.

Through the use of equation 3 the analysis of a conventional supply can be accomplished readily. Consider the circuit of Figure 2, with switch 1 in position A. For simplification, let

$$k = \frac{r_{p_1}}{R_1 + r_{p_1}}$$

$$G = \frac{\mu_1 R_1}{R_1 + r_{p_1}}$$

where T_n has associated characteristics μ_n and r_{p_n}. From equation 3 then

$$dE_2 = \frac{\mu_2 dE_1 + dE_0}{\mu_2 + 1 + \frac{r_{p_2}}{R_L}} \tag{6}$$

If the impedance of the reference gas tube is neglected,*

$$dE_1 = k\, dE_0 - G\beta dE_2 \tag{7}$$

When equations 6 and 7 are combined

$$dE_2\left(\mu_2 + 1 + \frac{r_{p_2}}{R_L}\right) = \mu_2(k\, dE_0 - G\beta dE_2) + dE_0$$

or

$$dE_2\left(\mu_2 + 1 + \frac{r_{p_2}}{R_L} + G\beta\mu_2\right) = (\mu_2 k + 1) dE_0$$

And

$$\frac{dE_2}{dE_0} = \frac{\mu_2 k + 1}{\mu_2(1 + G\beta) + 1 + \frac{r_{p_2}}{R_L}} \tag{8}$$

In most cases, $G\beta \gg 1$, $\mu_2 > 1$, and the ratio of r_{p_2} to R_L will be of the order of unity. To this approximation

$$\frac{dE_2}{dE_0} = \frac{\mu_2 k + 1}{\mu_2 G\beta} \tag{9}$$

Thus, if $\mu_2 k$ is large compared with unity, the regulation ability will be directly proportional to the product $G\beta$. In most cases this is relatively easy to achieve, and a fairly high order of stability for E_2 can be had. It should be apparent that equation 9 dictates the variation in E_2 for a given variation in E_0, whether the variation in E_0 is due to line voltage changes or harmonic ripple.

Somewhat improved characteristics can be obtained by setting switch 1 in Figure 2 in the B position. The analysis of this circuit is then similar to the preceding one. The difference between the circuits is in the source

* While the impedance of the usual gas tube reference is not entirely negligible in this circuit, its effect can be computed readily by considering that G is degenerated by the value of the gas tube impedance. If this impedance is R_c, then the accurate value of G, designated G', is

$$G' = \frac{\mu_1 R_1}{R_1 + r_{p_1} + (\mu_1 + 1) R_c}$$

If G' is high, then the approximation of equation 9 still will be valid. For other amplifier configurations, where R_c is not in the signal circuit, this refinement is not necessary, as R_c will cause no degeneration. Also, R_c will cause a slight change in k, but this is usually quite negligible.

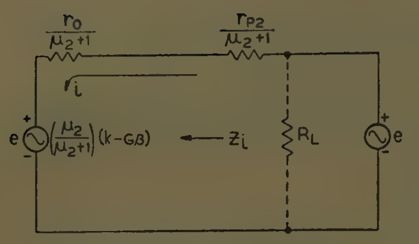

Figure 3. Equivalent circuit for derivation of internal impedance

of plate voltage for the tube T_1. With the same notation as before

$$dE_2=\frac{\mu_2 dE_1+dE_0}{\mu_2+1+\frac{r_{p_2}}{R_L}}$$

Here

$$dE_1=k\,dE_2-G\beta dE_2$$

So

$$dE_2\left(\mu_2+1+\frac{r_{p_2}}{R_L}\right)=\mu_2(k\,dE_2-G\beta dE_2)+dE_0$$

and

$$\frac{dE_2}{dE_0}=\frac{1}{\mu_2+1+\frac{r_{p_2}}{R_L}+\mu_2(G\beta-k)} \qquad (10)$$

Then to the same approximation as equation 9, with the additional requirement that $\mu_2 k$ be of the order of unity,

$$\frac{dE_2}{dE_0}=\frac{1}{\mu_2 G\beta} \qquad (11)$$

Thus, other things being equal, switch setting B will give a stabilization which will be $(\mu_2 k+1)$ better than that of setting A in Figure 2. As a practical matter this circuit always may not be most expedient. This notion is developed under "Practical Design Considerations."

To calculate the stability of E_2 for changes in R_L it is necessary to consider the impedance of a regulated supply looking back into its output terminals. For the circuit of Figure 2 (switch setting B), this internal impedance can be derived from the equivalent circuit. In deriving this equivalent circuit, let a voltage e be applied across R_L, and the resultant current calculated. The voltage amplifier T_1 will see a fraction β of the voltage e and will amplify the voltage to a value $-G\beta e$. Also, a fraction ke will be transmitted directly to the grid of T_2. The net voltage with respect to ground on the grid of T_2 then will be $e(k-G\beta)$. If the equivalent cathode circuit for T_2 is used then, there results the circuit of Figure 3. The current i then is

$$i=e\frac{\left[(k-G\beta)\left(\frac{\mu_2}{\mu_2+1}\right)-1\right]}{\frac{r_0+r_{p_2}}{\mu_2+1}} \qquad (12)$$

$$=-e\frac{[(G\beta-k)\mu_2+(\mu_2+1)]}{r_0+r_{p_2}}$$

As Z_i and R_L are in parallel, it is justifiable to omit R_L temporarily and to consider its shunting effect later. The ratio of $-e$ to i then gives Z_i, whence

$$Z_i=\frac{r_0+r_{p_2}}{(G\beta-k)\mu_2+(\mu_2+1)} \qquad (13)$$

The minus sign is inherent in the internal impedance, as Z_i is defined as $\partial E_2/\partial i$ which is a negative quantity.

As before, assume that $G\beta \gg 1$, $\mu_2>1$, and k to be of the order of unity. Then

$$Z_i=\frac{\frac{r_{p_2}}{\mu_2}}{G\beta}+\frac{r_0}{G\beta\mu_2}$$

$$=\frac{\frac{1}{g_{m_2}}}{G\beta}+\frac{r_0}{G\beta\mu_2} \qquad (14)$$

Either term usually will be quite small compared with R_L, so that the shunting effect of R_L can be considered negligible. The internal impedance varies inversely with product $G\beta$, and, if r_0 is small, the internal impedance will be $G\beta$ times less than the commonly accepted internal impedance of a cathode follower.

PRACTICAL DESIGN CONSIDERATIONS

The various design considerations follow; the order of presentation is of no significance.

Line Voltage Stability. One of the most obvious advantages of a regulated-voltage supply is its ability to provide a stabilized output for varying line voltage conditions. From equations 9 and 11, the effectiveness of this action can be calculated. A typical straightforward regulator will have a $G\beta$ product of about 100, and with the connection of Figure 2, switch setting A, corresponding to equation 9, the stabilization factor will be

$$\frac{dE_2}{dE_0}=\frac{4\times 0.5+1}{4\times 100}=\frac{3}{400}=0.75 \text{ per cent} \qquad (15)$$

if it is assumed that $\mu_2=4$, and $k=0.5$. Thus, a 40-volt change in E_0 will give a 0.3-volt change in E_2. To insure that the circuit operates satisfactorily over this range of input voltages, some care must be taken in setting the operating potentials for the cathode follower series tube. The two extreme conditions for this tube will be zero bias and maximum plate dissipation. The operating range can be

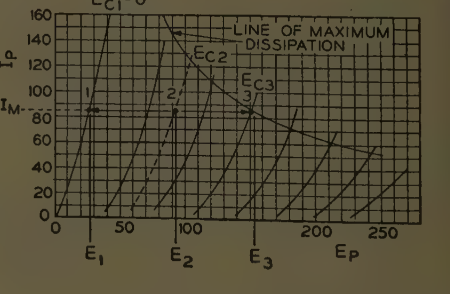

Figure 4. Type 6AS7G plate current—plate voltage characteristics

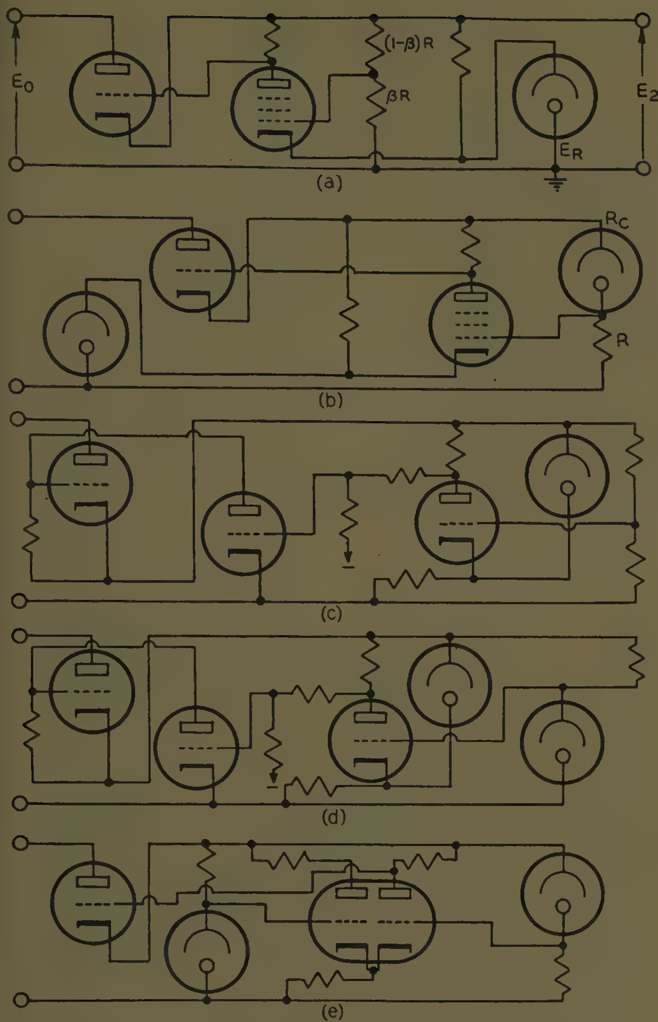

Figure 5. Typical voltage reference connections

illustrated graphically from Figure 4, where the I_p-E_p characteristics for a type *6AS7-G* dual triode are shown together with the maximum dissipation line. To specify properly the quiescent operating condition, the maximum load current I_M must be known. A horizontal line at I_M then will intersect the zero bias line ($E_{c_1}=0$) at point 1 and the maximum dissipation line at point 3. For nominal line voltage, the voltage drop across the series tube must be E_2, a point midway between points 1 and 2. The plate voltage for the d-c amplifier tube connected to the grid of the series tube then must provide the series tube with a nominal bias of E_{c_2} volts. The safe operating range for the series tube is then from E_1 to E_3 volts, with corresponding limits on line voltage.

If the line voltage varies at a relatively slow rate, the low frequency response of the d-c amplifier usually will be good enough to make the stability as high as that predicted by equation 9. However, the absolute stability is yet another matter. By absolute stability is meant the maintenance of a given value of E_2 over long periods of time. If the line voltage, and concurrently E_0, change by a large step increment, E_2, for the simple regulator, will change instantaneously only by an amount predicted by equation 9. Gradually thereafter, however, the value of E_2 will shift to a new value, depending largely on the spurious correcting voltage introduced by new contact potentials in the grid of the d-c amplifier. These spurious potentials apparently occur with a change in heater potential for the d-c amplifier tube. In an effort to provide relatively greater absolute stability, the circuit of Figure 9 has been proposed. Here an apparent balancing of heater variations is attained through the use of a difference amplifier. Some attempts to use this type of circuit have given both positive or negative drift in E_2 with variations in heater temperature, depending on the degree of balance in the two tubes comprising the difference amplifier. Caution in the use of this expedient is suggested, and, if absolute stability is a basic requirement, the elaborate safeguard of deriving the heater power from the regulated voltage supply itself is suggested. Such a circuit is shown in Figure 12.

Load Current Stability. To attain high stability for load current changes, a low internal impedance is required. From equation 14 it is observed that Z_i consists of two terms; consider the latter term first. The internal impedance of the supply for E_0 is r_0. For a choke-input supply, using a 200-ohm choke and a *5U4G* rectifier, a typical value of r_0 is 500 ohms. Capacitance input will increase this figure to 750 ohms. If the $G\beta$ product for a given regulator is 100, and $\mu_2=4$, the second term for Z_i has a value of 1.2 ohms. The first term, if a g_m of 7,500 is assumed for the series tube, gives a component of 1.33 ohms. Thus $Z_i=2.53$ ohms. Consequently, a 0.10-ampere change in load current will cause a change in output voltage of 0.253 volt.*

For circuit applications where such an internal impedance is excessively high, a higher loop gain is indicated. Two cautions are offered: (1) It is of little value to design a supply with, for example, a Z_i of 0.001 ohm, if in connecting the supply to the circuit in question, cables are used which have impedance comparable with the supply impedance. It is not sufficient to consider the impedance of the connecting cable at only d-c and low frequencies, as the internal impedance at higher frequencies also may be of importance, particularly for pulse work; (2) to maintain a very low value of Z_i over an appreciable range of frequencies requires that the $G\beta$ product remain constant over the specified frequency range. In multistage amplifiers, it may be difficult to do this and also avoid oscillation troubles. Consequently, it is often desirable to include a large capacitance across the output of the regulated supply to insure maintenance of a low internal impedance at higher frequencies, where for stability requirements the $G\beta$ product may be diminished purposely. The reasons underlying this choice are given in greater detail under "Causes of Oscillation."

* This figure is for low frequencies; r_0 may be appreciably lower at higher frequencies.

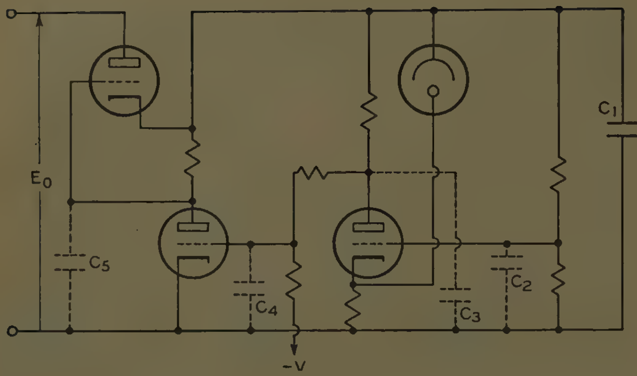

Figure 6. Circuit for a 2-stage regulator

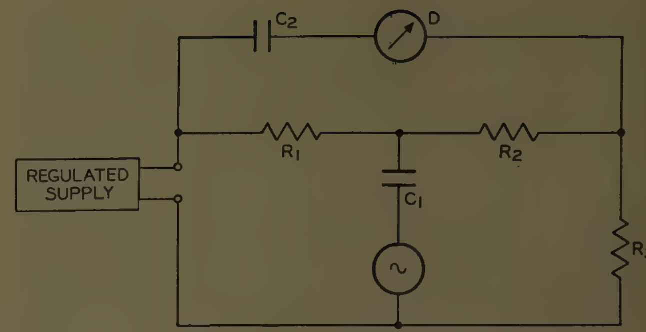

Figure 7. Bridge circuit for measuring internal impedance

For certain low-level video amplifier applications, extreme stability and low internal impedance are required for the power supply. Designers sometimes have resorted to "double regulated" supplies to gain the desired results. It now should be apparent that such a "double regulated" supply enjoys two advantages: (1) the second term, involving r_0, in the expression for internal impedance (equation 14) becomes indeed negligible, and the resultant internal impedance is limited only by the values of $G\beta$ and g_{m_2}; (2) the range of operating potentials for the second regulation stage is quite small, lending itself to optimum design. However, it would appear that comparable, if not better, results also could be obtained in a single stage regulator, provided that the $G\beta$ product is sufficiently high and that r_0 is not excessively large.

Ripple Reduction. The ability of a regulated-voltage supply to reduce ripple in general can be calculated on the same basis as line voltage stability, treated under "Line Voltage Stability." The ripple voltage for a 60-cycle-per-second supply will be predominately at 120 cycles-per-second, and its amplitude will be, in terms of the peak transformer voltage,

$$E_{\text{ripple}} = \frac{4}{3\pi} E_{\text{peak}} \tag{16}$$

Thus for a typical +300-volt supply using choke input, E_{peak} may be of the order of 510 volts, which would give an input ripple voltage of 215 volts. A single inductance-capacitance filter section consisting of a 10-henry choke and 10-microfarad capacitance would attenuate this ripple voltage to approximately 0.0173×215, or 3.73-volt, peak. If equation 15 is applied, this ripple would be reduced to $3.73 \times 3/400$, or 0.028-volt, peak. or 19.8 millivolts, rms. This ripple is probably tolerable for many applications; where lower ripple is desired, either more filtering can be employed, or the $G\beta$ product must be increased.

A caution is suggested here for those who would use the minimum inductance-capacitance filter. If a large value of ripple voltage is presented to the regulator, in the expectancy that it will supplant the filter, some care must be taken to see that the value of E_1 and E_3 in Figure 4 is

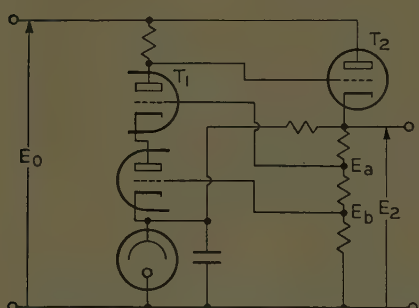

Figure 8. Voltage regulator—"cascode" type

$E_0 = +400$ *volts*
$E_2 = +250$ *volts*
$E_a = +164$ *volts*
$E_b = +150$ *volts*
$T_1 = 6SL7$
$T_2 = 6B4G$
$G = 1{,}250$
$\beta = 0.4$
$r_0 = 500\Omega$
$K = 0.75$
$\mu_2 = 4.0$
$g_{m2} = 5{,}000$ *micromhos*
$dE_2/dE_0 = 0.2$ *per cent*
$Z_i = 0.65\Omega$

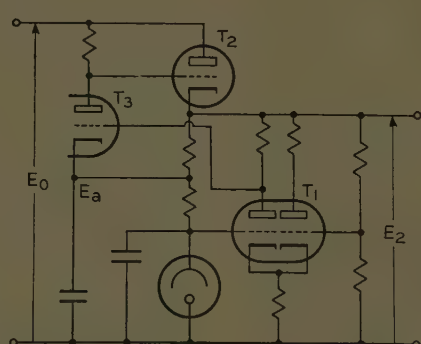

Figure 9. Voltage regulator—difference amplifier type

$E_0 = +400$ *volts*
$E_2 = +250$ *volts*
$E_a = +100$ *volts*
$T_1 = 6SL7$
$T_2 = 6B4G$
$T_3 = 6SL7$
$G = 1{,}500$
$\beta = 0.4$
$\mu_2 = 4$
$k = 0.05$
$g_{m2} = 5{,}000$ *micromhos*
$r_0 = 500\Omega$
$dE_2/dE_0 = 0.05$ *per cent*
$Z_i = 0.54\Omega$

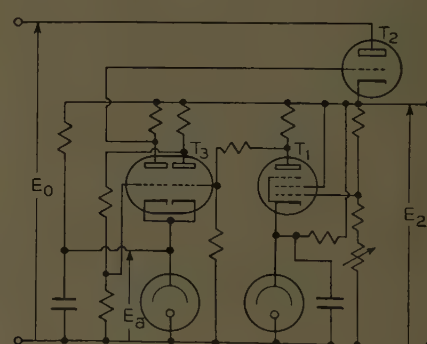

Figure 10. Two-stage amplifier for voltage regulation

$E_0 = +425$ *volts*
$E_2 = 300$ *volts*
$E_a = +150$ *volts*
$T_1 = 6AK5$
$T_2 = 2 \times 6AS7G$
$T_3 = 6J6$
$G = 8{,}000$
$\beta = 0.5$
$g_{m2} = 30{,}000$ *micromhos*
$\mu_2 = 2$
$r_0 = 500\Omega$
$dE_2/dE_0 = 0.013$ *per cent*
$Z_i = 0.071\Omega$

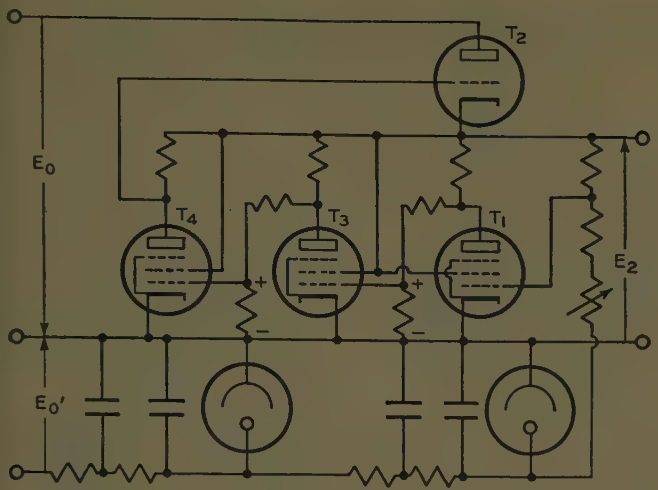

Figure 11. Three-stage amplifier for voltage regulation

$E_0 = +260$ volts	$G = 14{,}300$
$E_0' = +250$ volts	$\beta = 0.5$
$E_2 = +120$ volts	$GM_2 = 15{,}000$ micromhos
$T_1 = 6AK5$	$\mu_2 = 2$
$T_2 = 6AS7G$	$r_0 = 500\Omega$
$T_3 = 6AK5$	$dE_2/dE_0 = 0.007$ per cent
$T_4 = 6AK5$	$Z_t = 0.045\Omega$

not exceeded by the ripple. Otherwise, the regulator will lose control for the extreme excursions of input ripple voltage. Also, it should be mentioned that a minimum size inductance-capacitance filter also penalizes the line voltage stability design, unless extreme latitude in the $E_1 - E_3$ voltage range is available.

The residual ripple in a poorly constructed supply may exceed greatly the theoretically calculated value. Extra care should be taken to avoid chassis ground loops, electrostatic, or magnetic pickup of hum voltage in high impedance grid circuits. Where extremely low ripple is required, it may be necessary to derive the heater voltages for the regulation amplifier from a d-c source.

Voltage References and Their Connections. There are several basic connections for the gas tube voltage references commonly employed. These are shown in Figure 5. In Figure 5(*a*) is shown the common connection used with conventional supplies. In this case the amplifier gain is diminished by the factor β. As the amplifier tube operates at only a few volts grid bias, E_R will be related to E_2 by the approximation

$$\beta = \frac{\beta R}{(1-\beta)R + \beta R} \simeq \frac{E_R}{E_2} \qquad (17)$$

Thus, if $E_2 = 300$ volts, and $E_R = 150$ volts, β will be approximately 0.5. To recoup this loss in gain, it has been suggested that the resistance $(1-\beta)R$ be shunted by a capacitance. This will be effective at relatively high frequencies where this shunt reactance is negligible, but not for direct current; thus this connection should not be used where transient response is a major consideration. In Figure 5(*b*), an additional gas tube has been employed in place of $(1-\beta)R$, and the new loss factor then is reduced substantially for ripple frequencies as well as direct current. If R_c is the dynamic gas tube resistance, then the new β factor is

$$\beta' = \frac{R}{R + R_c} \qquad (18)$$

and this may be made very nearly unity in most cases. Some degree of freedom in the control variation of E_2 is lost by this artifice, however.

Figures 5(*c*) through (*e*) show alternative methods, (*c*) and (*d*) being applicable to 2-stage amplifiers, and (*e*) illustrating the use of a difference amplifier. Hamilton and Maiman[3] have shown how a negative voltage supply can be used where extreme flexibility in range of E_2 is required, allowing E_2 safely to approach zero volts.

Batteries and standard cells may be used as references, where greater stability is required. Experimentally, certain manufacturers' products have shown instability in gas tube reference circuits, thus some check on this fact should be made if great stability is desired. Also, most gas tubes show slightly irregular characteristics when run through their operating range, because of changes in ionization paths. Hunt and Hickman[5] have compared several of the available gas tubes with regard to stability for this application.

In passing, it also should be noted that, where a gas tube is used as a reference in a cathode circuit, or any other circuit where changing current conditions exist, it may be necessary to consider the effect of this variation on the reference voltage.

Causes of Oscillation. Broadly speaking, as one attempts to build better regulators, and resorts to higher loop gain and several amplifier stages, oscillations in the control amplifier must be avoided carefully. J. L. Lawson, of the Radiation Laboratory of Massachusetts Institute of Technology, states this by saying that the feed-back circuit must be degenerative at all frequencies where the loop gain is greater than unity. Careful analysis, using Nyquist's stability criteria, suggests that this always may not be readily accomplished unless certain precautions are taken. It is not convenient to treat this subject at length here, but certain basic precautions will be given. In a typical 2-stage regulator, more phase shift than the formal circuit diagram would indicate may take place readily. This is shown graphically in Figure 6. Here the formal circuit diagram is given, with all the unavoidable circuit capacitances indicated by dotted lines. The capacitance C_1 generally will be large to provide a low internal impedance at higher frequencies where the amplifier gain usually will diminish for stability reasons. C_2 and C_4 are the input capacitances for the amplifier tubes; C_3 and C_5 are the output capacitances. The combination of these capacitances and the impedances of their driving circuits may cause phase shifts which will result in the over-all amplifier to be regenerative when the loop gain is still greater than

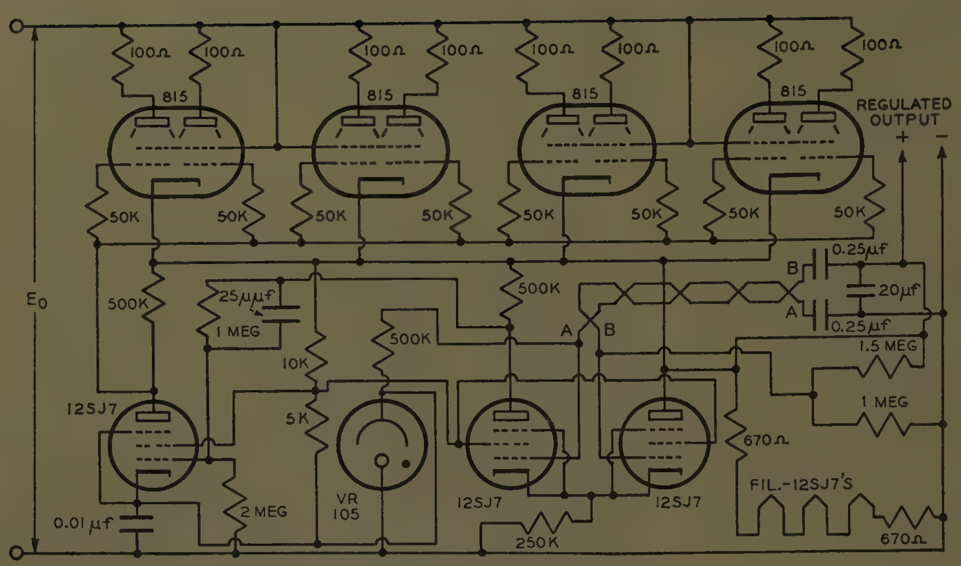

Figure 12. Improved voltage regulator

Regarding testing, the bridge methods suggested by Hunt and Hickman[5] are entirely adequate for routine testing. A simple alternative method of checking stabilization at a recurrent transient rate entails insertion of a line voltage "chopper" in the line voltage input circuit to the associated rectifier, causing, for example, a ±10 per cent variation in line voltage at a low repetitive rate, and observing the variation in E_2 on an oscilloscope. For measuring Z_i at audio frequencies and higher, a bridge circuit as shown in Figure 7 is suggested. In this case, the internal impedance is

unity. As a result then, the amplifier will oscillate, and the regulator will be unstable.

To attempt to correct this difficulty and achieve a stable amplifier may not always be simple. In general, a purely experimental approach is to add suitable capacitances to minimize this incidental phase shift, and purposely to limit the amplifier gain, so that the loop gain is less than unity at a frequency where the residual phase shift is above the critical value. The amplifier gain may be limited at any convenient point to accomplish this desired result. A more analytical approach is to break the feed-back loop and examine the gain-phase characteristic; suitable gain-phase correction networks then may be added to compensate the circuit as required. To cover the situation adequately, the feed-back amplifier must be absolutely stable under all load conditions.

Typical Circuits and Performance Data. Before discussing several typical circuits, some general remarks are in order. The basic objectives of regulator circuits may differ widely. For general laboratory work it may be desirable to employ a circuit which will provide regulated voltages the magnitude of which can be varied over wide limits. Alternatively, certain television applications require a fixed output voltage with high requirements of stability and a correspondingly low internal impedance. Also, through special compensation methods[1,5] it may be useful to attempt to gain an apparent zero internal impedance or perfect stabilization under special operating conditions. At the present time, these diverse requirements all cannot be met with one circuit; consequently, the several circuits now to be described each will offer particular advantages in respect to economy, stability, or internal impedance. Clearly, there is no need to employ a circuit inherently capable of much better regulation and stability than a device requires.

$$Z_i = \frac{R_1R_3}{R_2} \tag{19}$$

The detector D may be an amplifier oscilloscope, and C_1 and C_2 will isolate the signal source and indicator from the d-c path. If Z_i is a very low value, R_1 may be required to be a very low noninductive resistance. R_2 and R_3 may constitute the load for the supply.

Five circuits now will be given as typical of those in use for different specific applications. The conventional pentode regulator has been omitted as it has been well covered in the literature. Figure 8 shows the "cascode" circuit suggested by Hunt and Hickman[5] and used at the Radiation Laboratory at Massachusetts Institute of Technology and elsewhere, providing somewhat improved performance over the conventional pentode circuit. Figure 9 shows the difference amplifier suggested by R. M. Walker of the Radiation Laboratory, which offers improved d-c stability for drift, provided balanced tubes are employed. Figures 10 and 11 are circuits used at the Allen B. Du Mont Laboratories for certain television applications, and Figure 12 is a somewhat elegant supply, offering d-c stability through the use of regulated heater voltages; it is taken from Lawson's work. Typical calculated performance data are noted on each circuit; the notation used here is consistent with the preceding mathematical analysis.

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Machine Computing of Networks

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A widespread belief prevails among power system engineers that the problems of planning modern power system expansion are not solvable practically except with the aid of an analyzer. Certain principles and methods to facilitate the handling of problems of power flow networks make machine computation appear more feasible than the analyzer solution.

PLANNING of modern power system expansion demands that voltages, phase angles, power flow, and reactive power flow throughout the network be determined in advance of actual system changes. Determination by calculation of these quantities increases in difficulty to such an extent, as the system increases in size, that, for large interconnected systems, it heretofore has been considered necessary to use a network analyzer for this work. Since the first a-c network analyzer was put in service at the Massachusetts Institute of Technology in 1929, the scale model method of handling complex power system problems has grown in popularity, and the number and size of analyzers in the country has been increasing steadily. To date 14 network analyzers have been constructed, and more are on order, all at a total cost approaching $2,000,000.

Methods and equations for machine computation have been tested by recomputing an actual network analyzer study by mathematical means for comparison. Mathematical solution was made first with a key calculating machine. It was recomputed later by punched-card accounting machines to determine experimentally the time required and to standardize card design, coding, plugboards, and machine sequences to be suitable for the solution of any power network.

Although the saving of time by computing network problems with the network analyzer has been stressed, it is the belief of the author that, as mathematical understanding of the problems increases and machines for computation are improved, this saving of time will diminish so as to favor the mathematical over the analyzer solution. A sample study indicates that load studies may be computed in about the same time that they now are being solved with the aid of network analyzers, and that the mathematically computed solution will be of greater accuracy and will have been computed with less chance for error than the analyzer solution. If the network problem to be solved is extremely large, or contains a number of phase-shifting transformers, the advantage of the mathematical solution over the analyzer solution further increases. The afore-mentioned standards of speed and accuracy may be reached by performing the computations in the mathematical method with standard punched-card accounting machines.

The method of solving power networks described has been designed to fit a standardized problem, assuming that certain quantities are known and that certain other quantities are desired. In case the actual knowns and unknowns fail to fit the standardized problem, it is necessary to assume values to convert the problem to standard form and to check the answers against the desired knowns. Methods are described which may be used to check the reasonableness of assumed values by computing some few answers which are critically dependent upon the assumed values without computing the entire network.

The standardized problem consists of a set of known values, a set of answers to be computed, and a set of conditions to be satisfied by the answers. The known values are:

1. Circuit of the network.
2. Resistance of each impedance.
3. Reactance of each impedance.
4. Capacitive susceptance of each impedance.
5. Voltage ratio of each transformer.
6. Phase shift of each transformer.
7. Power load (or generation) at each bus in the network except one which is reserved to take up the slack due to system losses. This bus is referred to as the "slack-take-up bus."
8. Reactive power load (or generation) at each bus in the network except one.
9. Voltage at any one bus in the network.
10. Phase angle at any one bus in the network.

Answers to be computed are:

1. Power flow at each end of each impedance.
2. Reactive power flow at each end of each impedance.
3. Voltage at each bus.
4. Phase angle at each bus.

Conditions to be satisfied are:

1. Summation of power at each bus must equal zero, that is the power entering any bus must equal the power leaving it.
2. Summation of reactive power at each bus must equal zero.
3. Around each loop the summation of voltage drops must be zero.

Essential substance of paper 47-87, "Machine Computation of Power Network Performance," presented at the AIEE winter meeting, New York, N. Y., January 27–31, 1947, and scheduled for publication in the AIEE *TRANSACTIONS*, volume 66, 1947.

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4. Around each loop the summation of phase angle drops must equal zero.

Initial data for a problem are given in a master diagram (Figure 1) and in two tables. The master diagram is the circuit of the network; the first table indicates the line data for resistance and reactance of each impedance, and the voltage ratio and phase shift of each transformer; and the second table indicates bus data for power load at each bus in the network except one which is reserved to take up the slack due to system losses, this bus being known as the "slack-take-up bus," and the reactive power load at each bus in the network except one. The capacitive susceptance of each impedance is not given in the line data, but instead has been distributed among the busses and is included in the bus data.

As in the case of network analyzer solutions, it is most convenient to work in the per unit system, and all voltages, impedances, susceptances, powers, and reactive powers are so expressed. Because of the method of working with the small differences between the tangents and angles, phase angles must be expressed in radians.

MASTER DIAGRAM

The master diagram provides the link between the power network under consideration and the sequence of computations required to solve it just as the "plugging diagram" in network analyzer studies serves to co-ordinate the network analyzer units with the actual system being studied. The network is coded thoroughly by means of the master diagram, and computations may proceed for any desired set of loadings and transformer ratios without reference back to the master diagram. Despite the thoroughness with which the network is coded, the construction of a master diagram is simple and may be done by inspection and marking on a single-line diagram.

The following information is indicated on, or derivable from, the master diagram:

1. Each network element is assigned either a bus number or a line number. All network elements having a direction of flow of power or reactive power are assigned line numbers. Bus numbers are assigned to: points in the network where loads, generators, synchronous condensers, or susceptances are attached, junction points, and any other points at which it is desired to compute voltage.

2. Each loop in the network is assigned a loop number.

3. The network is divided into "tracks" each of which is assigned a track number.

4. A positive direction of flow is indicated for each network element bearing a line number. The positive direction of flow serves also to differentiate between the two ends of lines, sending and receiving.

5. Each network element in each track is assigned a track sequence number.

LOAD-LOSS FLOWS

For convenience in computing, the power flow in any particular network element is assumed to be composed of a known component, designated the "load-loss component"; and a set of components to be solved for as variables in loop-balancing equations, one variable component for each loop containing that particular network element. Each variable component is assumed to circulate around its loop, thereby satisfying, for all busses in the loop, Kirchoff's law that the sum of all currents flowing to a point is zero. Thus, if the load-loss components also are made to satisfy this law, the flow obtained by combining the components likewise will satisfy it.

SOLUTIONS ABOUT LOOPS

The satisfaction of conditions that around each loop the summation of voltage drops and phase angle drops must equal zero leads to the simultaneous solution of loop equations. By the method of successive approximations, the solution to make the summation of the voltage drops zero about loops is a separate process from the solution to make the summation of the phase angle drops zero about loops, the former involving a set of reactive power loop equations and the latter involving a set of power loop equations. Thus, each set of simultaneous equations contains only one variable for each loop, instead of two as would be the case if both the summation of voltage drops and phase angle drops were made zero in a single step. Further simplification is effected by holding the voltage, power loss, reactive power loss, and trigonometric functions to be known quantities, thus making the simultaneous equations linear.

In making changes in a computed solution, the simultaneous equation solution may assume greater importance, because only a small amount of additional computation may be required to obtain the equations or to expand the results. Thus, if the effects of a large number of changes are to be investigated, it may be of advantage to invert the matrix, that is, compute a set of coefficients which, when multiplied by the constant terms of the original equations, will give the variables directly. Since, for symmetrical equations, the inverted matrix also is symmetrical, the amount of computation required to invert the matrix is only slightly greater than the computation in a single solution to the equations.

EXPANSION OF LOOP SOLUTIONS

After the simultaneous loop equations have been solved, it is necessary to expand the variables and other data into a complete network solution for that approximation. For example, after the power equations have been solved, it is possible to compute power flow and voltage phase angle throughout the network. After reactive power equations have been solved, it is possible to compute reactive power flow and bus voltage throughout the network. Computation of the flow of power or reactive power may be made either by combining the variables with the load-loss flows, or by the same process as for load-loss flows with the extra component for the variable inserted and removed at the proper place in each loop track.

SUCCESSIVE APPROXIMATIONS

Rigorous equations for a direct solution for receiving power and receiving reactive power throughout the network would be difficult to solve; hence, a method of successive approximations has been developed. It may be demonstrated for any power network that the phase angle drop for most network elements is more dependent upon the flow of power than upon the flow of reactive power, and, similarly, voltage drops are more dependent upon the flow of reactive power than upon the flow of power. This circumstance may be used to advantage by holding receiving reactive power to be a known constant and receiving power the variable to be solved for when equating the sum of the phase angle drops to zero about each loop, and by holding receiving power a known constant and receiving reactive power the variable to be solved for when equating the sum of the voltage drops to zero, thus halving the number of simultaneous equations and variables by performing these solutions separately. Further simplifications result from holding the voltage, power loss, reactive power loss, and trigonometric functions to be known quantities when computing any one successive approximation.

The successive approximation method involves a series of steps as follows:

1. Assume a set of voltages and power and reactive power flows.
2. Compute power losses for each network element.
3. Compute an improved power flow, incorporating the computed losses and making the summation of the phase angle drop zero around each loop.
4. Compute reactive power losses for each network element, using the assumed voltage, reactive power flow, and the improved power flow.
5. Compute bus charging reactive power, using the assumed voltages.
6. Compute an improved reactive power flow, using the computed losses and improved power flow, and making the summation of the voltage drops zero around each loop.
7. Compute the voltage and the phase angle throughout the network, using the improved values of power flow and reactive power flow.

The cycle is restarted, using the improved values of power flow, reactive power flow, and voltage.

Convenient initial assumptions for network solution by successive approximations are receiving power equal to zero, receiving reactive power equal to zero, and per unit receiving voltage equal to one, throughout the network. Even using such crude starting values, it was found that the first approximation was of sufficient accuracy for purposes of adjusting the study to fit desired operating conditions, and the second approximation was of approximately the same accuracy as the network analyzer solution. In most cases it is believed that a third approximation would be of greater accuracy than are results obtainable from any network analyzer thus far developed. Computation is considerably simpler for the first approximation than for any succeeding approximation, because of the initial assumptions of zero flow.

The initial assumptions mean, physically, that power losses are zero, voltages are constant at the nominal value throughout the network, tangents of phase angles due to impedance drops are equal to the angles (or that the differences between angles and tangents cancel around each loop), and that phase shifts due to reactive power flow are zero (or cancel around each loop). Power systems ordinarily are designed to have small power loss and good regulation. Generally, they operate with small angles between busses, usually less than ten degrees and seldom exceeding 35 degrees. Phase shifts due to reactive power flow are also negligible compared with those due to power flow because, for most network elements, resistance is smaller than reactance and reactive power flow is smaller than power flow. Thus, although the first approximation for power flow is computed from very rough assumptions, it is fairly accurate, and all subsequent computations for power and other network quantities have better starting values.

MAKING CHANGES

One frequently cited disadvantage of mathematical methods of power network solution is the difficulty in making changes in a study once it has been completed. Experience indicates, however, that changes may be made readily in a completed, or partially completed, solution, being computed by the methods outlined in this article. The general method of solution may be divided into three processes: the funneling of a vast quantity of data into a set of simultaneous equations; the solving of the set of simultaneous equations; and the expansion of the simultaneous equation solution into a vast quantity of network answers. When it is desired to investigate the effect of a change in a network study, the information usually desired is the effect of the change upon a very limited number of network quantities. This problem may be solved readily by building upon a previously computed solution, because the amount of additional information to be incorporated into the simultaneous equations is limited and the equation solution need be expanded only to the extent necessary to obtain the desired information.

Attention is directed to the fact that this discussion of the effect of a change upon a computed network solution is based upon starting with the computed solution and working through a small portion of a single approximation. If greater accuracy is desired, other successive approximations must be solved, necessitating complete solutions to the network instead of short-cutting from the change to the effect as has been illustrated.

CONVERSION AND CORRECTION

After the computation of a network has progressed to the point where the solution is of sufficient accuracy

and bears sufficient similarity to the desired conditions, the results need to be converted to a form readily presentable for reports or other purposes. This process involves: correcting reactive power flows for $(1/2)E^2Y$ where E is sending or receiving voltage depending upon whether sending or receiving flow is to be corrected, and Y is susceptance; adding a constant angle to all phase angles to make the lowest one zero in some cases; converting data from the per unit system to actual quantities; converting phase angles from radians to degrees; and listing the answers. All this may be done mechanically.

EQUIPMENT AND METHODS

The International Business Machines equipment used for solution of the sample problem consisted of a *601* multiplying punch, *405* tabulator, *513* reproducing summary punch, and *080* sorter. The multiplying punch is designed to multiply groups of numbers which it reads from a card, and to punch the resulting product in the same card.

The tabulator is a combined adding, subtracting, and printing machine designed to read groups of numbers from cards, and also to respond to control punches in the cards. Groups of numbers on a single card may not be added together, but rather these numbers may be added to groups of numbers on other cards passing through the machine. By connecting the tabulator to a reproducing punch, summary cards may be punched with the same totals being printed, the process being termed "summary punching."

The reproducing summary punch is used to perform reproducing, summary punching, and gang punching. Reproducing is the transcribing of all, or any part, of the information punched on one set of cards into another set of cards, either in the original or in an altered sequence. Summary punching is the punching of a set of totals accumulated on the tabulator into a set of cards. Gang punching is the punching of identical information copied from a master card into a group of detail cards.

The sorter serves to divide a set of cards into several sets in accordance with the number punched in a particular column. If the several sets then are arranged in order into a single set, the original set of perhaps random sequence will have been rearranged into numerical sequence of the numbers in the particular column sorted on. The sorted set may be resorted in accordance with the number punched in another column to give a resulting set arranged in numerical sequence of 2-digit numbers formed by the two columns sorted on.

It is necessary that each card used in computing bear sufficient coding that the quantity on the card can be identified, and that the card may be sorted into any sequence required for computing. Positive identification is possible from the line number (or bus number) on each card and a set of numbers consisting of a number for each set of cards required in an approximation plus an approximation number. The line or bus numbers, loop numbers, track numbers, and track sequence numbers comprise the coding necessary for sorting the cards into sequence required for computing.

Each item of initial data is key punched into a separate set of cards. Thus, items in the statement of problem are punched in nine sets of data cards. The initial data also contain sets of cards showing the base voltage for each bus, blank line cards for all tracks, blank line cards, blank bus cards, and breaker cards (control cards to be sorted in at the end of each track to clear the tabulator total before starting another track).

After initial data cards are prepared, computation of load-loss power flows is the first step in the network solution. Initial data bus cards containing power loads, together with the blank line cards for all tracks and the breaker cards, are sorted into the order of track sequence numbers, considering the track number as the first digit (two digits had there been more than nine tracks) of a larger sequence number. This large set of cards, made up from the three smaller sets, then is run through the tabulator, taking a progressive total for each line number and summary punching the progressive totals. The summary punched cards next are sorted by line

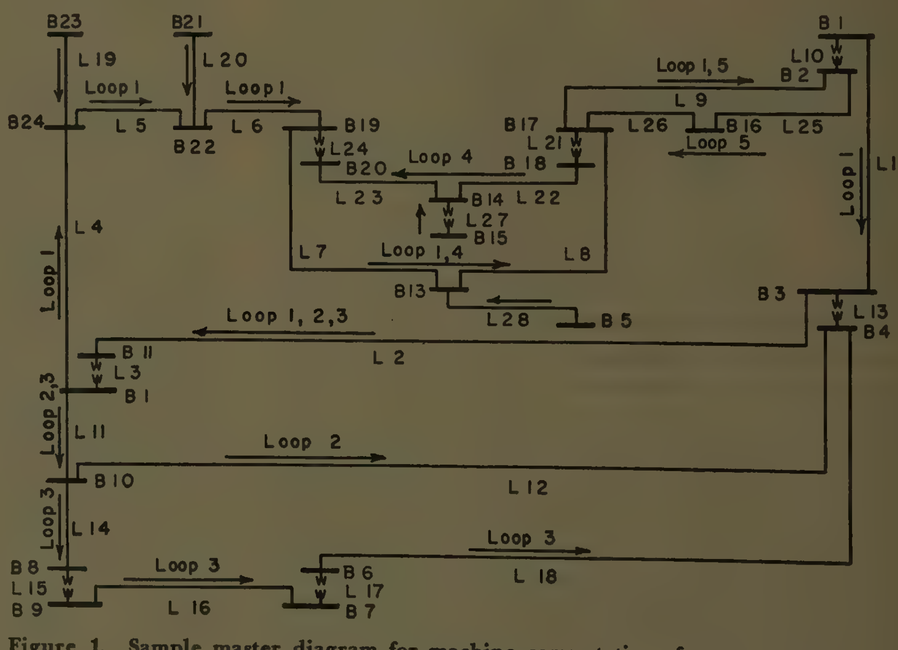

Figure 1. Sample master diagram for machine computation of power network performance

numbers and the sorted set then run through the tabulator, this time taking a total each time the line number is changed, and summary punching the totals. This second set of summary punched cards will contain the load-loss power flows for the first approximation and now may be run through the reproducer with the set of initial data cards containing the reactance of each line, to transcribe the load-loss flows and reactances to a set of cards for multiplying. After a run through the multiplier, this set of cards is then ready to sort by each loop number in turn and tabulate, thus giving the constant terms for the set of simultaneous power equations for the first approximation. The coefficients of the variables in the simultaneous equations are obtained by sorting by each loop a set of cards containing reactances, and then resorting the cards in each loop by each of the other loops, tabulating the results of each sorting. A schedule of operations similar to the foregoing, but resulting in the preparation of 50 sets of cards is involved in the computation of one complete approximation of a network solution.

For purposes of division and trigonometric functions, punched-card tables were prepared. The multiplying punch required two plugboards, one to multiply and the other to interpolate the tables of reciprocals. The reproducer required three plugboards, one for summary punching or for gang punching from the tables, another for reproducing card identification, and another for reproducing and gang punching the information for a given line into enough cards to accommodate all the loops containing that line. The tabulator board was arranged to perform either of two operations, depending upon the shifting of the total control impulse. In one case, it performed ordinary accumulation and summary punched the results by control groups. In the other case, it tabulated the coefficients of the simultaneous equations to be solved, and printed them in suitable form.

Every operation was reduced to a routine, requiring only the changing of plugboards and following of a fixed schedule. Fifty sets were required for one complete approximation, and two approximations were sufficient to give the results with the required accuracy.

GENERAL DISCUSSION

The multitudinous numerical computations involved in the solution of a network by the method outlined in this paper may be handled expeditiously by punched card accounting machines of the variety in daily use in most cities throughout the United States, and, in fact, in use for billing and payroll purposes in many of the larger power companies. It is not to be inferred that accounting machines are ideally suited to the solution of network load studies, but it is maintained that such machines can solve load studies without limitation as to size, and that load studies of the size and complexity presently being handled by network analyzers can be solved in comparable time with accounting machines. Progressively superior machines for computing purposes are being developed constantly, and if such a machine were adapted peculiarly to the solution of power system problems, it could, in all probability, outperform a network analyzer in speed, accuracy, versatility, and perhaps cost.

The test problem discussed herein was solved in approximately 70 hours computing time with a desk calculating machine, but required only ten hours to compute using a punched card tabulator, sorter, multiplier, and reproducer. Of such ten hours, the machines were idle approximately one third of the time because of time consumed in card handling, checking, and analysis. A total of approximately 4,000 cards was used in computations. Among the discoveries during the punched-card computation of the test problem, in addition to minor improvements in the system, was the fact that a larger study, perhaps ten times larger, would be a more appropriate size for the method. The test study had 28 impedances and 24 busses, so that many of the operations were performed on only 24 or 28 cards which would run through the reproducer in about one quarter of a minute, or through the multiplier in about $1^1/_2$ minutes. A larger study could be performed more efficiently because the time of starting and stopping the machines would be a smaller percentage of the operating time, and the running time would be long enough for the operator to prepare the next run, or perhaps to keep two or more machines running simultaneously.

Comparison of the mathematical method of network load studies with the network analyzer method indicates certain advantages and disadvantages of each over the other. The methods are not directly comparable since, with a calculating board, some solution to the network is always available for the reading whenever the board is plugged and energized, and the problem is to adjust the board so that the solution fits the desired loading and voltage conditions. With the analytical method the solution is not available until computed, but the computed solution will fit the desired loading with great precision. Small changes may be made readily in a board solution at the time it is in progress, but such changes would require some portion of the computed solution to be rerun, although, if the computing cards are preserved, the change may be made at any subsequent time. The board solution is subject to human errors of plugging, setting, and reading which are not detected readily, whereas, in the punched card solution, all transcribing and computing except for the punching of the original data, is done mechanically and may be listed mechanically for future reference and checking. The initial data and final answers may be printed in a form suitable to be incorporated into a report directly from the cards used in computing; whereas, with an analyzer solution, it is customary to have the answers drawn up in a drafting room for reports. Because of

the greater accuracy of the computed solution, power losses may be tabulated for all network elements, and, if desired, losses attributable to any particular load may be ascertained by computing load studies with and without the particular load.

A special advantage of a punched-card solution to a network is that all of the punched-card computations may be listed mechanically, and the list preserved for future reference. If, then, a modification of the original study is desired at some future time, the original computations may serve as a basis, and the few required additional computations may be conveniently performed with a desk calculating machine. The methods outlined for making changes may be used for this purpose.

The advantages of the analytical method over the network analyzer method of making load studies may be summarized briefly:

1. Great accuracy.
2. Less chance for error.
3. Neatness of automatically printed data and answers.
4. Easier and more effective filing of data for use in subsequent studies.
5. Computations may be listed automatically, so that a study may be modified easily with a desk calculating machine at any subsequent time.
6. Reactive flows in lines may be "corrected" automatically for $1/2E^2Y$.
7. No limitation to the size of the network analyzed.
8. Phase-shifting transformers offer no special difficulties.
9. Nontechnical help can perform computations.

The disadvantages are:

1. The computed solution is more difficult to modify than the network analyzer solution at the time it is being prepared.
2. The computed solution has not yet been systematized and mechanized for fault studies and transient stability studies.
3. Computed solutions lack a psychological advantage enjoyed by network analyzer solutions wherein measurements are taken on an actual electric circuit.

Magnetism and Angular Momentum

Mathematical physicists like Einstein and Schroedinger have been trying for some time to develop a single grand formula to unit gravitation, light, magnetism, and electricity. Back in 1891, Arthur Schuster suspected that every large rotating mass was a magnet. Michael Faraday conducted many experiments to show that light could be inflexed by magnetism and other forces, but failed. Regarding gravity, he wrote in his diary: "Surely this force must be capable of an experimental relation to electricity, magnetism, and other forces, so as to bind it up with them in reciprocal action and equivalent effect."

Faraday was speaking of what today is called a "unitary field theory." He failed to prove his concept experimentally, because it is impossible to measure the very small magnetic and gravitational effects that can be produced in the laboratory with manageable masses and forces.

According to the *New York Times*, Professor P. M. S. Blackett (University of Manchester) has developed Schuster's suggestion and produced both mathematical and observational evidence that a large spinning mass of necessity must be a magnet. He has shown that the faster the spin, the more pronounced is the magnetic effect.

To put the new law to test, the angular momentum of a few planets or stars had to be known. Until recently only the angular momentum or magnetic field of the earth had been measured accurately, though that of the sun could be inferred from spectrographic evidence.

Fortunately, earlier this year, H. W. Babcock of Mount Wilson Observatory had published some measurements of the fifth magnitude star, 78 Virginis, so that there was a third large body which could serve as a test mass. Subsequent measurements showed that the ratio of the magnetic strength to angular momentum was just about what it ought to be for 78 Virginis.

Professor Blackett has connected the mechanical properties (angular momentum) of a planet or a star with magnetism. Moreover, his fundamental equation includes a symbol that stands for what physicists call the "constant of gravitation," so that we have a suggestive linking of angular momentum, magnetism, and gravity.

The equation reads

$$P=\frac{\beta G^{1/2}U}{c}$$

where

P = magnetic moment
U = angular momentum
G = gravitational constant
c = velocity of light
β = constant ≈ 1

It may be that the long-sought formula which will give us unitary field theory will come out of Professor Blackett's work. In fact, the unitary field theory is necessary to explain his new natural law.

Dielectric Loss at High Frequency

J. B. WHITEHEAD
FELLOW AIEE

In the application of dielectric heating to various industrial processes, alternating frequencies between 1 and 30 megacycles, and rates of temperature rise of 50 degrees Fahrenheit and upward, are common. The measurement of the dielectric properties of a material under such varying conditions presents a problem which may be solved by a calorimetric substitution method.

THE heating of dielectrics under alternating electric stress has been recognized since the early days of high voltage power transmission. With increasing values of voltage and frequency, the losses in insulators have assumed great importance, and have placed a premium on the development of low loss insulating materials. On the other hand, in relatively poor insulators the losses may be so great, and the heating so rapid, that this method of heating has replaced, with advantage, steam and other agents or many industrial heating processes on composite materials having moderate insulating characteristics.

The engineering of dielectric heating for large industrial processes is not yet clearly developed. The losses are apparently the result of dielectric absorption, or interfacial polarization, and are greatest somewhere within the frequency range 1 to 100 megacycles. So far, however, knowledge of the changes in value of the electric constants of the material being heated, over the range of temperature of the process, is wanting. In most cases a rapid heating cycle is desirable, and rates of temperature rise of 60 degrees Fahrenheit per minute, or higher are common. Moreover, it often happens that it is not possible to interrupt the heating cycle without impairing the efficiency of the curing process and the quality of the resulting product.

THE PROBLEM

Consequently, the problem presented is that of the measurement of the dielectric properties of a material during a period in which its temperature is changing rapidly. Most of the methods already developed for the measurement of dielectric loss at, say, ten megacycles and upward, are substitution methods, involving two or more settings (see American Society for Testing Materials designation *D150–44T*—for example, ASTM shunted susceptance variation method) and voltage gradients so low that no appreciable change in temperature resulting from dielectric loss occurs during the measurement. Such methods, therefore, are not suitable for the problem before us. Calorimetric methods for the measurement of power loss usually involve a hot steady state and the measurement of temperature gradients in the ambient medium.[1] Such methods are either time consuming or involve elaborate protection of the ambient field in which the temperature gradients are measured. However, if the volume of the dielectric is fairly large and the duration of the heating cycle several minutes, it should be possible, by means of a proper selection and location of d-c electric heaters, either to duplicate in another sample the a-c heating curve, or to derive it in a point-by-point method of equivalent thermal input. This is a substitution method therefore; and while not in the "precision" class, it nevertheless has yielded a very satisfactory degree of accuracy.

THE METHOD

If a mass of dielectric material is completely insulated thermally, and if its thermal properties do not change with rising temperature, then when it is supplied with thermal energy uniformly and at a constant rate, its temperature will increase linearly with time up to some temperature of destruction. If the thermal insulation is very good, though not perfect, the temperature–time curve will have an initial approximately linear portion, the gradient beginning to fall off only after the lapse of an appreciable time. This condition has been utilized for d-c calibrations in the method described in the following.

If the dielectric with high thermal insulation is supplied with high-frequency electric energy, as in a cell such as shown in Figure 1, the loss constants of the dielectric increase with increasing temperature, the rate of energy input (by dielectric loss) increases, and the temperature–curve soon loses its initial linear character, and rises with rapidly increasing gradient toward a temperature of combustion or breakdown (see Figure 4).

In Figure 1, *A* is the dielectric of flat cylindrical form; *B*, the high and low tension electrodes, the latter consisting of central member and outer guard ring; *C*, backing plates of "Formica"; and *D* a surrounding cylinder of "Transite"; these two materials have low thermal con-

Full text of paper 47-158, "Dielectric Heating, the Measurement of Loss Under Rising Temperature," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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The author acknowledges the support of the Armstrong Cork Company, Lancaster, Pa., at whose request the work was done; the co-operation of Doctor G. W. Scott, Jr.; and the assistance of Doctor C. Frank Miller, Doctor F. G. Whelan, W. Rueggeberg, and C. B. Boenning in the experimental work.

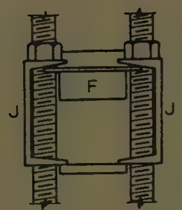
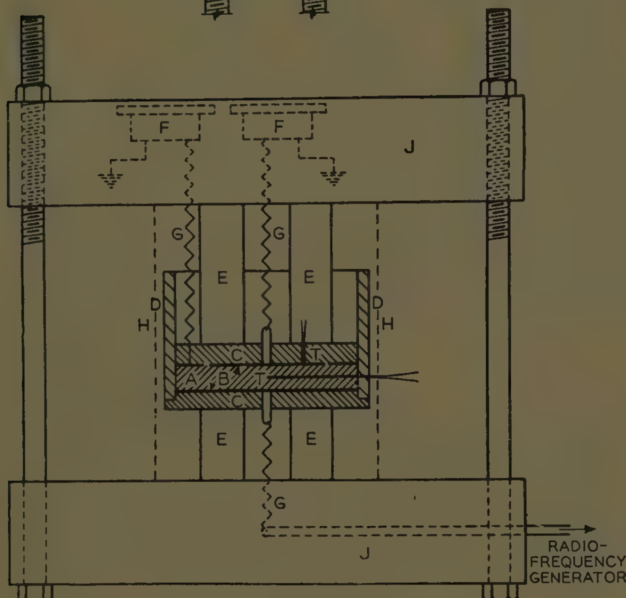


Figure 1. Test cell



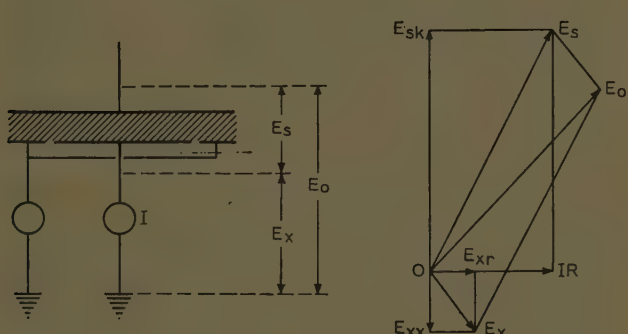


Figure 2. High-frequency measurement

$$E_{sk}=\sqrt{E_o^2-(IR+E_{xr})^2}+E_{xx}$$

$$E_s=\sqrt{E_{sk}^2+IR^2}$$

$$IR=\frac{\textit{heating watts}}{I}$$

$$\textit{Power factor}=\frac{IR}{E_s}$$

$$K=\frac{I}{E_{sk}}\times \textit{constant}$$

ductivities and high tensile strength. The whole measuring cell is mounted on steatite pillars E, and within an outer steel framework J equipped for applying pressure to the sample A. Radio-frequency thermoammeters F read the currents from main and guard electrodes to ground. Temperatures are read by the thermocouples T. H is an electrostatic screen surrounding the cell.

The simple electric connections are shown in Figure 2, together with the vector diagram of voltages. The diagram also includes the vectors for the small inductive

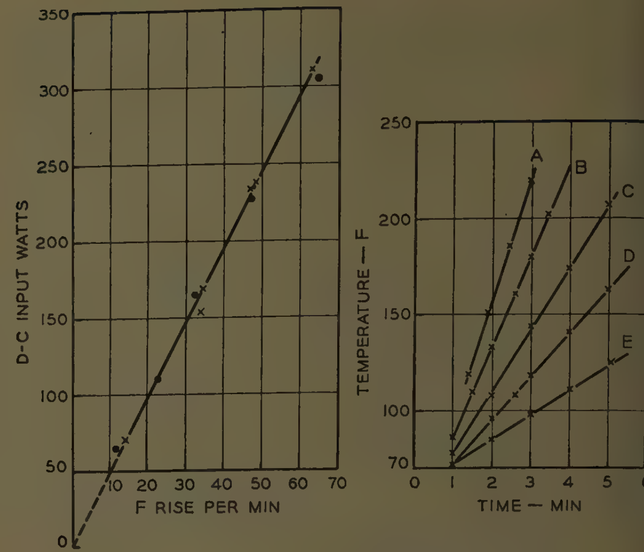


Figure 3. D-c calibration curves

A—307.5 watts, 64.6 degrees Fahrenheit per minute
B—228.7 watts, 47.7 degrees Fahrenheit per minute
C—166.1 watts, 32.3 degrees Fahrenheit per minute
D—110 watts, 22.8 degrees Fahrenheit per minute
E—64.5 watts, 11.88 degrees Fahrenheit per minute

impedance of the ammeter and connection to ground. Voltage across the sample is read on a vacuum tube voltmeter. Thus current and voltage are read directly, and if the total heating watts are obtained by d-c calibration, the IR component in the vector diagram is known, and K, cos θ, tan δ, and other quantities are derived at once.

D-C CALIBRATION

For the d-c calibration a duplicate cell is constructed identical in all respects with the a-c cell except that, instead of the electrode system, two, three, or more heating grids of thin sheet nichrome are inserted at the outer surfaces of the dielectric, and at times within its mass. The a-c electrodes are of the same material as the heaters, and the amount and location of all materials in the a-c and d-c cells is very closely the same. In calibrating, the d-c cell filled with an equal amount of dielectric replaces the a-c cell in the cell mounting, and a constant value of continuous current is applied to the heating circuit. Internal temperatures again are read with the needle thermocouple. After about one minute the temperature throughout the mass of the specimen becomes approximately uniform and increases linearly with time as shown in Figure 3 (for several values of heating current). The linear relation continues for five, six, or more minutes when the curve begins to fall off as the cell begins to lose heat. Each of these curves in its linear portion represents a uniform rise of temperature, that is, a temperature–time gradient of so many degrees rise per minute, corresponding to a uniform supply of energy in watts resulting from the constant heating current. The family of heating curves may be combined in one curve showing heating watts as function of rate of rise of

temperature, also shown in Figure 3. It will be noted that this curve is also a straight line up to 50 or 60 degrees Fahrenheit per minute; it passes through or near to a zero point of no energy and no temperature rise; and beyond 60 degrees per minute turns upward slightly, as the cell begins to lose heat at large values of d-c energy input.

EXPERIMENTAL RESULTS

Figure 4 shows the average location of the heating curves of two variations of the same material, each mixed with a binder, put under pressure in the cell of Figure 1, and heated by applying electric stress of 0.8 volt per mil at ten megacycles. The rate of heating is controlled readily by varying the applied voltage. Temperature, current, and voltage can be read at one-half-minute intervals. A tangent to the heating curve at any point gives the rate of temperature rise at that point. The corresponding rate of energy input, that is, watts, may be taken from the d-c calibration curve. If R is the effective resistance of dielectric heating, then the d-c watt input may be written as I^2R, in which I is the measured high-frequency current corresponding to the point in question of the heating curve. The vector IR of Figure 2 is now known and all quantities readily computed. Values for the two materials in question, of power factor, dielectric constants, tan δ, and loss factor are plotted in curves of Figures 5 and 6.

ACCURACY

As to accuracy, the instruments used ensure precision measurements within say one per cent or two per cent. More important, however, are variables resulting from the rapid changes of temperature in the upper range, and the time interval necessary to adjust the thermopotentiometer; and from inherent variations of the material under test from one sample to another. The latter is reflected at once in the initial value of the high-frequency current, which may vary by as much as five to ten per cent in successive otherwise identical samples. For samples showing the same value of starting current, the heating curves repeat quite closely. An example for three specimens is shown in Figure 7.

The method is the more accurate the longer the heating cycle and the better the thermal insulation of the a-c and d-c cells. For a long cycle a differential thermocouple circuit between the a-c and d-c cells in simultaneous excitation should be possible, allowing continuous adjustment of direct current to balance the a-c input. For short cycles this is not possible, for the direction of heat flow in the two samples is not the same, and a definite time interval is necessary for the equalization of temperature throughout the d-c specimen. This is, in fact, a chief limitation of the method. The a-c energy is developed uniformly throughout the sample, the direct current is applied by heater grids. However, this difference may be reduced by subdivision of the sample, increasing the number of grids, and by other methods. In the 3- to 6-minute cycles described, satisfactory uniformity of temperature in both a-c and d-c samples is reached after one minute.

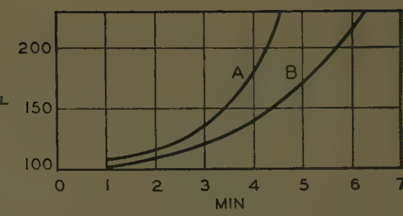


Figure 4. Temperature-time curves

400 volts, 10 megacycles

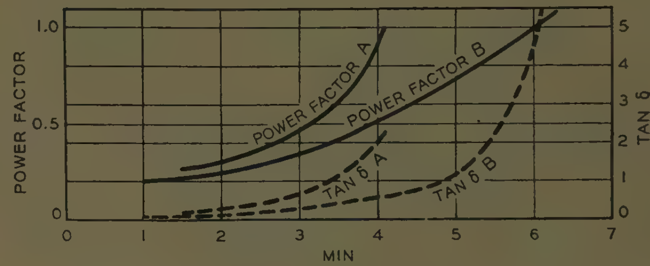


Figure 5. Power factor and tan δ

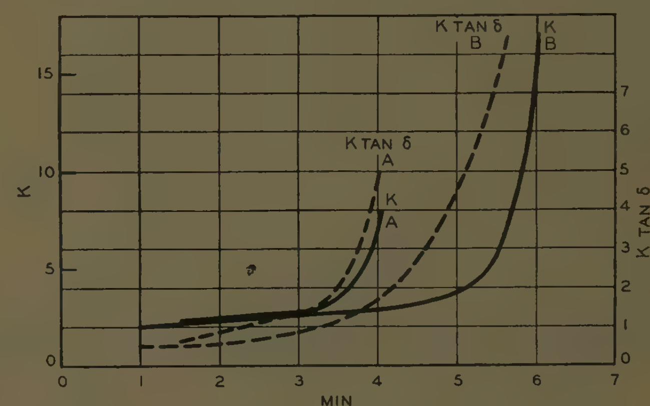


Figure 6. K and K tan δ

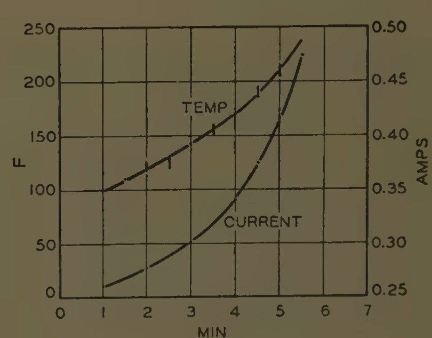


Figure 7. Material A

Current and temperature versus time

DISCUSSION

The chief advantage of the method, as here described, is the simplicity of the linear d-c calibration shown in Figure 3. This, in turn, results from the relatively good thermal insulation, and the relatively low curing tem-

perature of the materials, that is, less than 250 degrees Fahrenheit. For higher temperatures, thermal insulation is more difficult, linear d-c heating curves become shorter, and further subdivision of sample and heaters must be introduced. Best of all corrective measures is a longer heating cycle.

From Figure 4 it will be seen that power factor and loss factor increase rapidly with increasing temperature, the former reaching nearly the value "unity" at the end of the cycle (225 degrees Fahrenheit); beyond this point the material begins to burn. The dielectric constant also increases; less rapidly during the early stages, and more rapidly, in fact towards an infinite value, as the power factor approaches unity.

Two pictures of the mechanism of dielectric heating present themselves. First, interfacial polarization: The conductivities of internal conducting paths of limited length increase rapidly with increasing temperature, causing greater resistance losses under the rapid reversals of the absorption component of the charging current, thereby resulting in increasing values of power and dissipation factors. As a second cause there is molecular polarization. This, in general, would give the same type of behavior as interfacial polarization, although not coincident therewith over a range of frequency. The question of their relative importance can be answered best by measurements over a range of frequency. Studies in this direction are under way.

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2. Principles of High-Frequency Heating, **L. Hartshorn.** *Chemistry and Industry*, number 37, September 9, 1944, pages 322–5.

Aging Tests on Class *A* Insulation

AIEE TRANSFORMER SUBCOMMITTEE

THIS REPORT gives the results of aging tests conducted by four co-operating laboratory groups of the General Electric Company, Pittsfield, Mass.; the Westinghouse Electric Corporation, Sharon, Pa.; the Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; and the Illinois Institute of Technology, Chicago, Ill.

The purpose of the tests was to determine whether the tensile strength of class *A* insulation (Manila paper) sealed in tubes with oil and protected from the air continues to decrease with time or whether the strength decreases to a certain percentage of its initial strength and then very little, if any, for long periods of time.

Tests were made at 100, 120, and 135 degrees centigrade. The 120- and 135-degree tests are completed. The 100-degree tests are still under way and will run for one or two years more.

Essentially full text of paper **47-127**, "Preliminary Report on Laboratory Aging Tests on Class *A* Insulation," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in the AIEE *TRANSACTIONS*, volume 66, 1947.

Personnel of subcommittee on transformers: F. S. Brown (F '45), Duquesne Light Company, Pittsburgh, Pa., *chairman;* M. K. Brown (M '34), J. E. Clem (F '38), H. L. Davis (M '43), I. W. Gross (F '45), H. B. Keath (F '39), V. M. Montsinger (F '29), J. R. North (F '41), W. C. Sealey (M '38), F. L. Snyder (M '46), F. J. Vogel (M '41), C. F. Wagner (F '40), H. H. Wagner (F '43), E. R. Whitehead (F '45).

Members of working group: V. M. Montsinger, General Electric Company, Pittsfield, Mass., *chairman;* P. L. Bellaschi (F '43), W. C. Sealey (F '45), and F. J. Vogel.

The subcommittee is indebted to the following men and organizations for assistance rendered:

The General Electric tests, under F. M. Clark's supervision, were conducted by S. W. Kernaghan.

The Westinghouse tests, under the supervision of Doctor C. F. Hill, were conducted by L. McCulloch.

The Allis-Chalmers tests were conducted by J. P. L. McCoy, W. H. Krause, and J. M. Doherty.

The Illinois Institute of Technology tests were made under the supervision of Professor F. J. Vogel, with the help of L. W. Matsch of the Armour Research Foundation in making the measurements.

The oil and paper were furnished by the Westinghouse Electric Corporation. The test samples were treated and sealed in the test tubes by the General Electric Company.

DESCRIPTION OF MATERIALS (PAPER AND OIL)

Manila Paper From Manning Paper Company:

Ash content, per cent	1.1
Alpha cellulose, per cent	88
pH of extract, per cent	7.6
Apparent density, gram per cubic centimeter	0.65
Porosity or air resistance, seconds	37

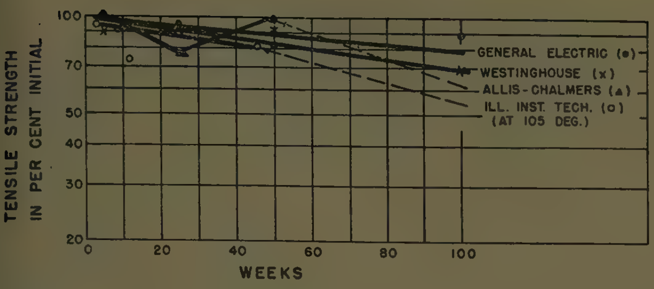

Figure 1. Aging of Manila paper at 100 degrees centigrade

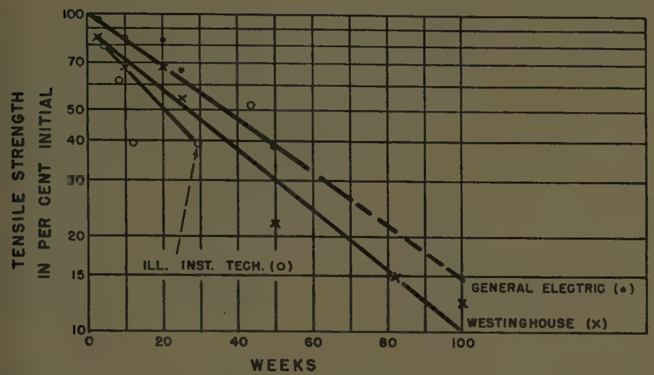

Figure 2. Aging of Manila paper at 120 degrees centigrade

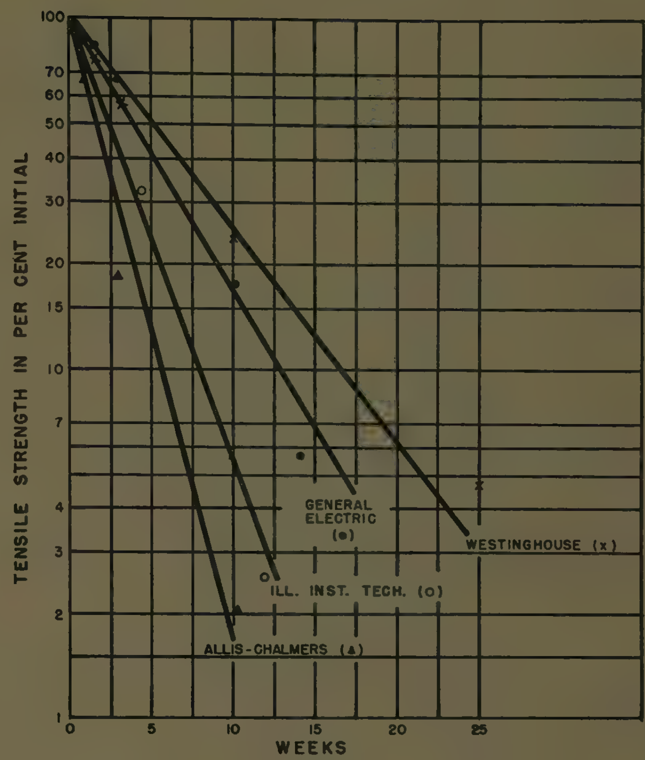

Figure 3. Aging of Manila paper at 135 degrees centigrade

Carbon tetrachloride solubles, per cent....................0.57

Transformer Oil. Wemco *C* transformer oil.

PREPARATION OF TEST SAMPLES

Strips of Manila paper (0.0033 by 0.5 by 10 inches), formed into a $3^1/_2$-inch coil and tied with cotton string, were inserted into Pyrex test tubes, (25 by 200 millimeters). The tubes were constricted to a 1/4-inch neck 6 inches from the bottom. All test samples were vacuum dried and impregnated with Wemco *C* oil. Excess oil over 50 milliliters was removed from tubes. They were flushed with dry nitrogen and immediately sealed at room temperature and atmospheric pressure.

1. Amount of paper: 13 strips 0.0033 to 0.5 by 10 inches or 2.2 grams (dry weight) per tube.
2. Amount of oil: 50 milliliters oil (and paper) per tube.
3. Ratio paper to oil: 5 per cent paper, 95 per cent oil.
4. Gas space: 15 per cent nitrogen gas, 85 per cent oil (and paper).
5. Vacuum treatment: All test samples vacuum dried in one tank at 112 degrees centigrade for 24 hours of broken vacuum followed by 72 hours of fine vacuum (500 to 800 microns). Oil impregnated while hot. Soaked under vacuum while cooling.
6. Drying of oil: Wemco *C* oil dried to 10 parts per million water content before impregnating by bubbling with dry nitrogen.
7. Water content tubes: 0.74 milligram per tube. Based on dry paper weight, the water content of the paper would be 330 parts per million.

Results are reported for a series of co-operative laboratory aging tests made on oil-impregnated Manila paper sealed in glass tubes.

INFORMATION ON TESTING METHODS

General Electric Company

Tensile Strength. Schopper tester, 125-millimeter gap. Samples tested immediately on breaking tube. Tested at 70 degrees Fahrenheit and 50 per cent relative humidity. Values given are the average of ten tests.

Folding Test. Tinius Olsen folding endurance tester. One-kilogram load. Records number of double 90 degrees bends.

Oil Color. American Society for Testing Materials units, by comparison with known oil standards.

Oil Acidity. Solvent method, titrating with NaOH. Results calculated to milligrams KOH per gram.

Westinghouse Electric Corporation

Preparation of Paper Samples and Tensile Strength. All test strips were extracted with heptane and were conditioned for 24 hours at 65 per cent relative humidity and room temperature. Testing machines used were a Scott 0 to 50 pounds, a Schopper 0 to 10 pounds, and a Tinius Olsen 0 to 10 pounds. Testing spacing was five inches. Tests were made according to ASTM *D202-43.* Values given are the average of five tests. Tensile strength is expressed in percentage of unimpregnated paper.

Oil Color. ASTM units, by Union colorimeter.

Oil Acidity. Titration by 0.02 normal KOH.

Table I. Summary of 100-Degrees-Centigrade Aging Tests

Aging Time, Weeks	Tensile Strength: Lb Per In.$^2\times10^3$	Tensile Strength: Per Cent Initial	Elongation, Per Cent	Folding Test, Number, Double Folds	Oil Color, ASTM	Oil Acidity, Mg KOH Per G
General Electric Company						
0	14.1	100.0	1.3	90	1/2	0.005
5	13.9	98.7	1.1	74	1/2	0.004
25	13.5	95.8	0.8	53	1/2	0.003
50	11.7	83.0	0.6	16	1	0.007
100	12.6	89.4	0.4	7	1	0.025
Westinghouse Electric Corporation	Per Cent					
0	106	100.0	2.4		Less than 1	0.012
5	97	91.5	1.1		Less than 1	0.012
25	98	92.5	3.1		1	0.017
50	98	92.5			1	0.020
100	72	68.0				
Allis-Chalmers Manufacturing Company	Lb				National Petroleum Association	
0	22	100.0				
5	22	100.0			1.2	0.012
25	17	77.3			1.2	0.013
50	22	100.0				

Armour Research Foundation (aged at 105 C)

Aging Time, Weeks	Tensile Strength: Lb	Tensile Strength: Per Cent Initial	Elongation: In. Per 8 In.	Elongation: Per Cent	Tear Tests: Force, G	Tear Tests: Per Cent Strength	Power Factor, Per Cent	Specific Inductive Capacity	Oil Acidity, Mg KOG Per G
0	23.2 (avg)	100.0	0.23	2.9	60	300			0.035
4.6	21.7 (avg)	93.6	0.11	1.4	33	55	0.9	2.16	0.05
8.66	21.1	91.0	0.11	1.4	35	58			0.052
12.0	17.1	73.7							
29.6	19.7	85.0	0.10	1.25	13	22			0.054
42.7	10.03	82.1	0.08	1.0			0.13	0.217	0.060

Table II. Summary of 120-Degrees-Centigrade Aging Tests

Aging Time, Weeks	Tensile Strength: Lb Per In.$^2\times10^3$	Tensile Strength: Per Cent Initial	Elongation, Per Cent	Folding Test, Number Double Folds	Oil Color, ASTM	Oil Acidity, Mg KOH Per G
General Electric Company (average of two separate tests)						
0	14.1	100.0	1.3	90	1/2	0.004
3	13.6	96.5	1.0	75	1/2	0.005
10	11.7	83.0	0.6	3	3/4	0.016
25	7.9	66.0	0.25	1	1	0.026
50	5.4	38.3	0.15	1/2	1	0.085
75	1.54	11.0	0	0	1	0.160
Westinghouse Electric Corporation	Per Cent					
0	106	100.0	2.4		Less than 1	0.012
3	89	83.9	2.1		1	0.017
10	72	67.9	1.5		1	0.012
25	57	53.7	1.0		1	0.012
50	23	21.7			1	0.02
82	16	15.1				
100	13	12.3				

Armour Research Foundation

Aging Time, Weeks	Tensile Strength: Lb	Tensile Strength: Per Cent Initial	Elongation: In. Per 8 In.	Elongation: Per Cent	Tear Tests: Force, G	Tear Tests: Per Cent Strength	Power Factor, Per Cent	Specific Inductive Capacity	Oil Acidity, Mg KOH Per G
0	23.2 (avg)	100.0	0.23	2.9	60	100			0.035
4.6	20.6	88.8	0.09	1.1	27	45	0.11	2.17	0.056
8.6	16.3	70.3	0.09	1.1	21	35			0.057
12.0	9.1	39.2							
29.6	9.1	39.2	0.05	0.6	(0)	0	0.15	2.16	0.062
42.7	11.9	51.4	0.05	0.6	(0)	0	0.21	2.26	0.087

Allis-Chalmers Manufacturing Company

Method of Testing for Tensile Strength. After the vials were broken, the paper and oil were transferred immediately to a clean dry jar with an airtight seal. The strips of paper were removed from the jars and tested immediately without removing any of the oil, and without conditioning the samples to the humidity of the room in a Henry L. Scott tensile testing machine readable to the nearest one-half pound. Paper held at 135 degrees centigrade for three weeks and over was difficult to handle because of brittleness. The values given are the average of five tests.

Oil Acidity. Given in milligrams KOH per gram by titration.

Table III. Summary of 135-Degrees-Centigrade Aging Tests

Aging Time, Weeks	Tensile Strength: Lb Per In.$^2 \times 10^2$	Tensile Strength: Per Cent Initial	Elongation, Per Cent	Folding Test, Number Double Folds	Oil Color ASTM	Oil Acidity, Mg KOH Per G
General Electric Company						
0	14.1	100.0	1.3	90	1/2	0.004
1	12.7	90.1	0.9	9	1/2	0.027
3	9.5	67.4	0.7	1	1/2	0.064
10	2.5	17.7	0	0	1	0.10
14	0.8	5.7	0	0	1 1/4	0.09
Westinghouse Electric Corporation	Per Cent					
0	106	100.0	2.4		Less than 1	0.012
1	89	84.0	1.3		1	0.012
3	66	62.2	1.0		1	0.017
10	25	23.6			1	0.023
25	5	4.7			1 1/2	0.058
50	0				Less than 2	0.100
Allis-Chalmers Manufacturing Company	Lb				National Petroleum Association	
0	22	100.0				
1	15	68.2			1.3	0.012
3	4	18.2			1.3	0.018
10	<1	(2.0)			1.5	0.040

Armour Research Foundation

Aging Time, Weeks	Tensile Strength: Lb	Tensile Strength: Per Cent Initial	Elongation: In. Per 8 In.	Elongation: Per Cent	Power Factor, Per Cent	Specific Inductive Capacity	Oil Acidity Mg KOH Per G
0	23.2 (avg)	100.0	0.23	2.9			0.035
4.6	7.7	33.2	0.04	0.5	0.22	2.16	0.059
8.6	Brittle						0.071
12.0	0.6	2.6	0.002	0.025	0.37	2.16	0.129

Oil Color. National Petroleum Association units.

Armour Research Foundation

Tensile Strength. Tested with a Thwing-Albert tensile tester, with the pull adjusted to increase at four pounds per second. The results were expressed as pounds pull at failure. The test spacing was eight inches. Special care was used to cushion the pull at the clamps. Tests made immediately after sample had cooled and glass tube opened.

Tear Test. Expressed as force in grams and tested with an Elmendorf tear tester.

Fold Tests. Some tests were made with a Tinius Olsen fold tester, but because of the large variation, they were not considered as a satisfactory indication and the tests are not included in the results.

Oil Acidity. Neutralization number obtained by ASTM procedure expressed in milligrams KOH per gram of oil.

Power Factor. Oil from tubes tested at 100 degrees centigrade in a cell at 60 cycles.

RECORD OF TEMPERATURES

General Electric Company. The 100-degree-centigrade temperature was plus or minus 1.0 degree with no overheating.

The 120-degree-centigrade temperature was plus or minus 2.0 degrees, averaging close to 120 degrees centigrade, and twice the temperature was 124 degrees centigrade over night.

The 135-degrees-centigrade temperature was plus or minus 0.5 degree and was low at 129 degrees for two days

Westinghouse Electric Corporation. The temperature of the three ovens did not exceed two degrees above the nominal values, and 80 or 90 per cent of the readings fell between the nominal temperatures and three degrees below. The average temperatures of the ovens from the 270 daily readings are 99.5, 119.4, and 134.4 degrees centigrade.

Allis-Chalmers Manufacturing Company. The oil samples were aged at 100 and 135 degrees centigrade in a Precision Scientific Company oven with temperature control resulting in a temperature variation of less than one degree.

SPREAD FROM AVERAGE TENSILE STRENGTH

General Electric Company. Above 38 per cent the initial strength of the variation was 6 to 14 per cent. Below 38 per cent the variation was from 24 to 70 per cent.

Westinghouse Electric Corporation. Above 40 per cent of initial strength the spread was from plus or minus 2.5 to plus or minus 7.5 per cent from average. Below 25 per cent the spread was from plus or minus 25 to plus or minus 50 per cent from average.

SUMMARY OF TEST RESULTS

The results of the tests made at the four laboratories are given in Tables I, II, and III. The per cent initial strength versus time data are plotted in Figures 1, 2, and 3, respectively.

The Electrical '47's

An interesting historical survey of electrical happenings in the 47th year of earlier centuries appears in the January 10, 1947, issue of the English magazine *Electrical Review*. Many events of interest to electrical engineers occurred in earlier '47's. In 1647, for example, Otto von Guericke constructed the first electric machine, which consisted of a globe of sulphur, cast in a glass sphere (which afterwards was broken to remove the sulphur globe). With this primitive machine, its inventor, in the words of Humboldt, "heard the first sound, and saw the first light, in artificially produced electricity." A century later, Benjamin Franklin announced his theory of a single fluid, terming the vitreous electricity "positive" and the resinous "negative." At a picnic in the following year he "killed a turkey by the electric spark, and roasted it by an electric jack before a fire kindled by the electric bottle."

On June 1, 1747, Franklin wrote a letter to Peter Collinson which Sir William Watson found helpful in starting in the same year, with the aid of the astronomer, John Bevis (who suggested strengthening the charge of a Leyden jar by coating it with tinfoil), and other members of the Royal Society, his lengthy series of experiments on "the velocity of electric matter." Watson conveyed a shock across the Thames at Westminister Bridge—a test which, by proving the instantaneous transmission of electricity through great distances, was the germ of telegraphic communication.

It was in that year that John Canton, who has been described as one of the most successful experimenters in the golden age of electricity and the first Englishman to emulate Franklin's experiments, began to concentrate on the production of magnets by artificial means.

Among other events of 1747, Gowin Knight was awarded the Copley Medal for his magnetic researches (which originated in his observing the effects of a flash of lightning upon a ship's compass), and Benjamin Martin's "Philosophia Britannica" followed his popular "Essay on Electricity."

With the passing of another century arrived the birth year of men who are a personal memory instead of merely names in history. Such was Thomas Alva Edison (born February 11, 1847), who, when a telegraph operator, read Faraday's works on electricity, acquiring thereby inspiration for his brilliant sequence of inventions. Then there was Alexander Graham Bell (born March 3, 1847) who culminated his researches into the problem of transmitting sound by electricity and light with the invention of the telephone.

Many other electrical celebrities were born in 1847. William Edward Ayrton (September 14) studied electricity under Kelvin, created the pioneer laboratory for teaching applied electricity, and was responsible (in conjunction with Perry) for a series of inventions exceeded in number only by Edison's. Thomas Andrew (February 16) conducted researches on the effects of chemical solutions on magnetized iron or steel and observed that a current was produced when the opposite poles of two electrically connected magnets of about equal strength were immersed in solutions of various chemical substances.

Other notables born in 1847 were: Sir Alfred Greenhill (November 29), the mathematician, noted for his research on the applications of elliptic functions and in dynamics; Charles Frederic Moberly Bell (April 2) who, as managing director of the *Times*, was the first to establish a system of wireless press messages across the Atlantic; Andrew Gray, who was assistant to Kelvin and author of "Absolute Measurements in Electricity and Magnetism" and of a treatise on "Magnetism and Electricity"; and Alexander Siemens (January 22) who assisted in building the Indo-European telegraph line and the Black Sea cable, and was responsible for the arc lighting of the Albert Hall and British Museum.

The obituaries of 1847 included: James McCullagh (October) a mathematician who introduced the studies of electricity, galvanism, heat, and terrestrial magnetism into the fellowship course at Dublin University; and Patrick Murphy (December 1) who became famous (as a weather prophet) for "Murphy's winter" but supplemented that fortunate guesswork by more solid achievement as author "Rudiments of the Primary Forces of Gravity, Magnetism, and Electricity in Their Agency on the Heavenly Bodies."

Whereas in 1747 the great genius in electricity was Benjamin Franklin, in 1847 he was Michael Faraday, whose second great period of discovery had begun. Perhaps the outstanding event of the year, however, stands to the credit of James Prescott Joule. He had been engaged for some years in researches regarding the relations between heat, electricity, and mechanical work. That year he read a paper on the subject before the British Association at Oxford, creating a great sensation, according to Kelvin (then William Thomson). "Faraday," stated Thomson, "was there, and was much struck with it, but did not enter fully into the new views. It was many years after that before any of the scientific chiefs began to give their adhesion." At that meeting Thomson read a paper on his theory of electric images; the publication that year of Helmholtz's work "On the Conservation of Energy" was an inspiration to Thomson in his researches exceeded only by the stimulus of Joule's thesis.

Sir William Robert Grove (inventor of the Grove cell) assisted in the reconstruction of the Royal Society in 1847 and was awarded the Royal Medal for his paper, "On the Gas Voltaic Battery", and his lecture on "Certain Phenomena of Voltaic Ignition."

Sir Charles Wheatstone planned a submarine telegraph between Dover and Calais, and John Watkins Brett obtained permission from the French king, Louis-Philippe, to attempt to establish telegraphic communication between France and England. Meanwhile Wheatstone had dissolved partnership with Sir William Forthergill Cooke, who, in the preceding year, had played a principal part in the formation of the Electric Telegraph Company. The American Telegraph Company adopted, in 1847, House's type-printing telegraph, in which the motion of the wheel carrying the type at the receiving station was produced step by step by the teeth of a wheel at the transmitting end, making and breaking an electric circuit as it was rotated.

William Petrie began in 1847 the invention of the first truly self-regulating arc lamp, which was designed "to impart more surely such motions to one of the electrodes that the light may be preserved from going out, be kept more uniform, and be renewed by the action of the apparatus itself whenever it has been put out."

Staite improved the electric lamp which he had invented in conjunction with Greener and exhibited it at the Hanover Square Rooms. Sir Graves Champney Haughton detailed in the *Philosophical Magazine* experiments to prove the common nature of magnetism, cohesion, and viscosity, and William Snow Harris was knighted in recognition of the introduction of his lightning conductors into ships of the Royal Navy.

Improved City Transportation

W. J. CLARDY
MEMBER AIEE

Trolley coaches and PCC streetcars established a high degree of availability and usefulness meeting World War II demands and have a definite economic field of application for city transit ranging from 500 to 12,000 maximum passengers per hour in one direction. They offer efficient use of city streets and reduction of traffic congestion.

PEOPLE expect low cost and convenient means of travel between various sections of a city. Adequate transit establishes the required access to shopping and delivery districts, expands residential territory, and avoids the concentration of workers in homes near offices and factories. The growth of every large city depends on quick travel within the metropolitan area. Development and application of new vehicles must keep pace with this demand for utility in city transportation.

CITY TRANSIT PROBLEM

The rapid rise of transit traffic during 1941, 1942, and 1943 carried the level of travel up to 70 per cent above that for the years 1936 through 1940. There was a further moderate increase in 1944, and the past two years have been close to 80 per cent ahead of the 1936–1940 average. The amount of business during 1946 was the equivalent of nine people being transported in comparison with each five for the 1936–1940 period.

The heavy demands placed on city transit systems, particularly in the war years, required both ingenuity and resourcefulness to meet service needs. The situation was complicated further by the existing inadequate supply of modern transit vehicles and the limitations placed on the production of new units. Inability to obtain sufficient maintenance personnel reduced the work which could be done to the minimum that would keep vehicles running. The objective was to provide a maximum amount of essential transportation with the least expenditure of materials and labor.

City transit systems gained a substantial number of passengers due to "necessity riding" created by wartime restrictions of automobile travel. The importance of retaining a major portion of these riders was appreciated, and long before hostilities ended means of providing service to accomplish this result were being studied.

Essential substance of paper 47-147, "Trolley Coaches and PCC Street Cars Provide Successful City Transportation," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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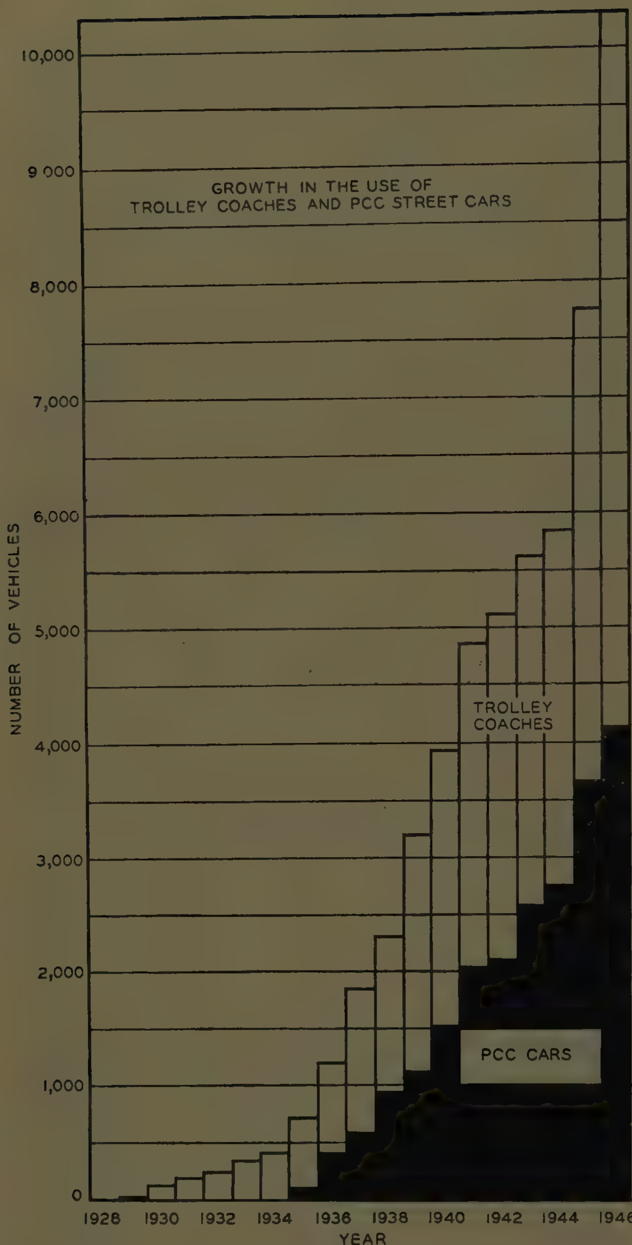

Figure 1. Trend of trolley coach and PCC streetcar use

The problem was recognized as one of vital economic importance to the urban transit industry. It involved replacing all old vehicles with modern types as rapidly as practicable. Fortunately, the use of public urban transit facilities has continued at a high rate since the end of the war for a much longer period than was anticipated. This has provided a greater opportunity for modernization before passengers change their riding habits.

MEETING TRANSIT DEMANDS

The trolley coach and PCC streetcar have proved their usefulness and economic soundness for city transit service. The modern version of the former vehicle started its career in 1928, and the latter was used first in 1936. The increased "use trend" for the two vehicles is best illustrated by Figure 1.

Trolley coaches and PCC streetcars have a wide range of economic usefulness in city transit service. The former can be applied for maximum hour travel as low as 500 passengers in one direction. It is the most efficient unit up to 2,500 passengers per maximum hour, and in many cases, is successfully handling much heavier traffic. The low point for the streetcar starts at 2,500 and goes up to 12,000 passengers per maximum hour in one direction. The latter figure represents 150 vehicles per hour on a 60 foot street—30 second headway—with loading equivalent to $1^1/_2$ times the seating capacity. This compares with possible peaks of 180 vehicles per hour and loadings equal to $2^1/_2$ times seating capacity. When travel exceeds 12,000 passengers per maximum hour for one direction, rapid-transit trains are required.

Trolley coaches and PCC streetcars established exceptional availability records during the war years when the sharply upward trend of transit traffic was in progress. The long life of parts when renewal items were scarce and the minimum amount of attention needed from depleted maintenance personnel contributed substantially in providing essential transportation service. A 100 per cent availability record was often attained and close approximation of this performance was a normal expectancy.

EFFICIENCY AND QUIETNESS

The limited capacity of city streets in metropolitan areas and the congestion caused by the automobile have made city dwellers realize more and more that "street use" is a civic problem. Large expenditures for widening, even where such measures are practicable, rarely prove to be a solution. Much can be gained by judicious allocation of existing street space. The elimination of parking and more general use of public transit vehicles are important factors (Figure 3).

Trolley coaches and PCC street cars are among the quietest vehicles operating on city streets. This is illustrated by Figure 5, which compares vehicles on the basis of tests in Cleveland, Ohio, and New York, N. Y.

TROLLEY COACH PERFORMANCE

The modern trolley coach as equipped by one manufacturer is propelled by a single 140-horsepower 600-volt series motor which can develop 235 horsepower for starting. A typical 12-ton average loaded coach requires less than 200 horsepower to start at 3.5 miles per hour per second. Availability of ample power for rapid acceleration is an important factor in maintaining fast schedule speed. The series motor has the inherent characteristic of increasing rapidly dynamic braking as speed goes up, and it has capacity for sufficient dynamic braking to reduce the duty on brake drums and linings to a degree that permits obtaining long life—two years or more.

minimum running time with varying degrees of street congestion, rapid stops produced with combined dynamic and drum braking, and the ability to maneuver around slow-moving vehicles and street obstructions.

Figure 2. Trolley coaches at terminal of heavily traveled line

Control apparatus of the same manufacturer is an assembly of cam group and unit switches which have operating coils suitable for a 12-volt battery and generator power source. There are 15 accelerating steps designed to give equal tractive effort increments, thus, providing smooth rapid starts. Acceleration gradually decreases with the attainment of higher coach speed until power is cut off. There are 13 control steps for dynamic braking, and the provision of equal increments of braking effort maintains a smooth rate of braking from 40 to 3 miles per hour.

The trolley coach is capable of maintaining schedule speeds of 12–15 miles per hour in urban service with 7–10 stops per mile. Tests made to check actual operation show that average schedule speeds are at least 80 per cent of the maximum. The vehicle has set a new standard for fast travel over congested city streets made possible by the availability of ample motor capacity to give rapid starts, a speed range that permits

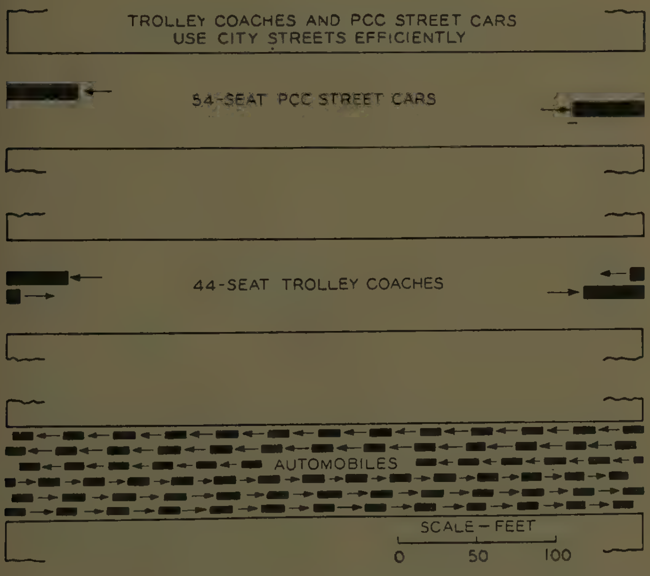

Figure 3. The chart shows actual space occupied by 81 passengers traveling in each direction by different means

Average automobile loading—2 passengers

PCC CAR PERFORMANCE

The propulsion equipment of the PCC streetcar consists of four 55-horsepower 300-volt series motors—

Figure 4. PCC car loading at safety island

220 horsepower per car. It requires 300 horsepower to start a 21-ton loaded car at 3.5 miles per hour per second, and 365 horsepower are available to make the rapid accelerations required by high-speed service. Sufficient capacity is provided to permit service dynamic braking and it is used for all normal stopping. The deceleration rate obtainable with a 21-ton loaded car is 3.15 miles per hour per second. The series motor gives a quick build-up of dynamic braking, provides simple braking connections, and facilitates equal division of braking duty among the four machines.

Control apparatus includes a line switch, a group of contactors for setting up the main circuits, and an accelerator for adjusting resistance when starting and stopping. The latter device, which is the most important item, has 99 steps for cutting resistance in and out of the motor circuits, which results in such small tractive effort increments that acceleration remains practically constant after the selected rate is attained. The same situation exists during dynamic braking, and the full rate is carried down to almost zero speed. Dynamic braking is supplemented by four motor shaft drum brakes and four track brakes. Drum braking and track braking are used in emergency while the former completes the stop after dynamic braking "fades out" (about $1^1/_2$ miles per hour) and holds the car after it stops. Also, drum braking functions whenever the dynamic brake is inoperative. The control power for accelerating, braking and all auxiliary circuits is

supplied from a 32-volt storage battery so that the various devices can function even in case of a dewirement.

PCC streetcars can operate with schedule speeds 25 per cent, or more, above those maintained by old street cars. A comparison showed the PCC car able to maintain a schedule speed of 18.8 miles per hour at four stops per mile and 10.8 miles per hour at 12 stops per mile for maximum performance. For the same conditions the old streetcar maintained speeds of 14.5 and 8.5 miles per hour respectively. Average performance, which includes turns, traffic signal delays, and street traffic interference, is somewhat slower.

The necessity for retaining a high traffic volume on city transit systems is the urge for modernization. Prior

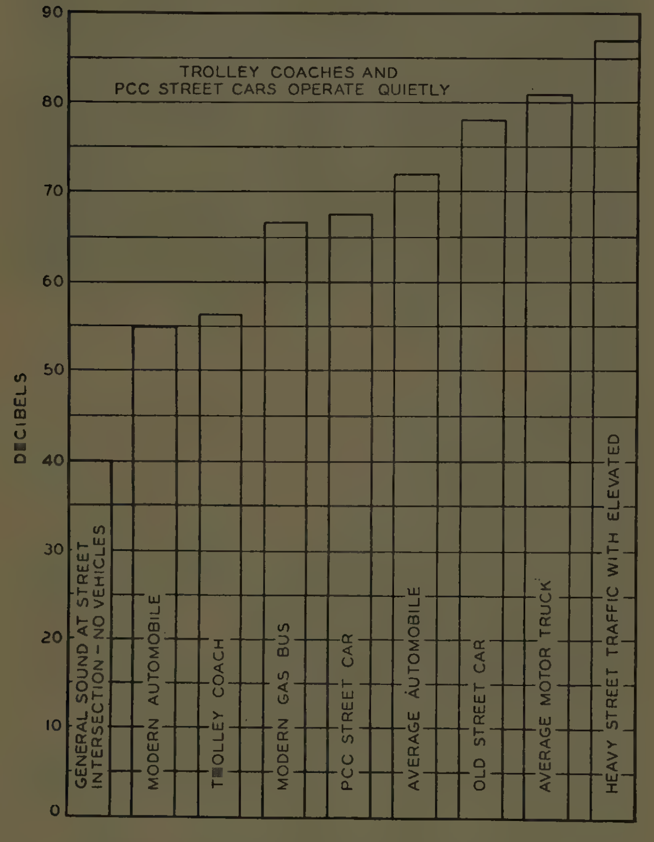

Figure 5. Comparison of vehicle operating noise

to the war, the trolley coach and PCC streetcar both demonstrated their ability to increase revenues in competition with other means of travel. Trolley coaches produced improvements of 25 to 35 per cent while typical gains for PCC streetcars ranged from 10 to 15 per cent. Thus, the two vehicles have proved their ability to attract passengers.

A conservative saving in operating expenses for the trolley coach is three cents per vehicle mile in comparison with the motor bus, PCC streetcars effect savings in track and roadway maintenance, equipment maintenance, transportation costs and accident expense when compared with old streetcars while power costs tend to increase. However, the important factor in each case is the gain in revenue that these modern vehicles will produce in competition with other means of travel, as was demonstrated prior to World War II. The economic advantages can be utilized in modernization programs and should be used more extensively.

TROLLEY COACHES AND PCC CARS NEEDED

Trolley coaches and PCC streetcars have been applied generally on city transit systems. These vehicles are the product of considerable engineering effort to provide a comfortable ride, improve performance, and increase operating efficiency. Results are creditable as a contribution to the betterment of city transit facilities, and the new units will assist substantially in meeting the needs of modernization programs. Action should be taken to expand the installations of these vehicles and thereby realize the benefits of the improvements in urban transit.

Cleaning Glass by Electronic Bombardment

A new method of cleaning optical glass by electronic bombardment, developed by the Bausch and Lomb Optical Company, is reported in the July 1947 *Compressed Air Magazine.*

Ordinary looking glass is coated on the back, but high precision mirrors are coated on the front or first side in order to eliminate distortion caused by dual reflection of the image. Before the ground and polished glass can be coated, however, it must be free from dust and the minute residue of moisture that is always present on any surface. Drying can be effected only by heat, but aluminum, which is the metal applied, will not adhere to a heated surface.

In order to apply the new technique, the glass is placed in a metal holder mounted above a tungsten filament like that in ordinary incandescent lamps. After preliminary dusting, the bell is lowered and the filament is heated electrically to a temperature at which electrons are emitted. Because electrons are negative particles, they are attracted by the holder which is at a high positive potential with respect to the filament. The electrons bombard the glass at high speeds and leave the exposed surface free of matter and moisture.

Unlike other methods, electronic bombardment heats only the surface, which cools almost instantaneously to the same temperature as the remainder of the optical glass. The aluminum film then will adhere.

Modulation in Communication

F. A. COWAN
FELLOW AIEE

IN ANY signaling system, the process by which the conditions at the sending end are changed, so that they may be recognized at the receiving end, has come to be called "modulation." Many varieties of forms of change exist as well as a large number of conditions which are subject to change in response to the signals to be transmitted. For modern communication, systems in which the signals change the magnitude or condition of electric energy are especially widespread.

The fundamentals involved in introducing signals into one medium and transmitting them through another are simplified in this review, so that the relationships between the many varieties of modulations attempted or in contemporary use are formed into a cohesive whole.

Starting with the electric telegraph a little more than a hundred years ago, this medium of communication has grown steadily more important and more complex. To meet a variety of needs, many systems of modulation have been developed. Some of the earlier conceptions of modulation processes have acquired a classical textbook status. Recent trends have placed emphasis on modulation systems which may be understood more readily when viewed in a somewhat different manner. This article presents certain conceptions which may facilitate the understanding of the various systems of modulation and permit an improved perspective.

TYPES OF MODULATION

Communication by electrical means depends upon wave transmission. The information a wave transmits is determined by the manner in which the instantaneous wave magnitude varies with time. All modulation systems depend upon changing in some way this relationship between magnitude and time. Early telegraph and telephone systems employed a change of amplitude in response to the signals. Though most of the present-day systems also depend upon amplitude changes of some form, in many systems the amplitude of the waves is not changed, and the intelligence is transmitted by changing the relative phase or time of occurrence of some periodic wave condition. As the frequency of a wave is merely the rate at which a periodic wave recurs, a variation in the relative time of occurrence represents a change in frequency as well as phase.

Systems of modulation which employ amplitude changes are designated broadly as "amplitude modulation" systems. Those employing changes in time of occurrence may be designated as "frequency modulation," "phase modulation," or "time modulation" systems.

CHANGING THE SIGNAL MEDIUM

Translation of signals from one medium to another involves modifying conditions in the new medium in response to those in the originating medium. For transmission, electric signals are converted from acoustic signals in the telephone, from mechanical signals in the telegraph and teletypewriter, and from light signals in television and telephotograph systems. At the receiving point another step of modulation, "demodulation," changes the signals back to the originating medium.

When, as is usually the case, the electric signals are produced by changing the magnitude of an otherwise unvarying quantity, such as might be produced by a direct current or voltage, the signal frequencies are the same as those in the originating medium. These frequencies are called "keying," "audio," and "video" frequencies for the telegraph, the telephone, and television, respectively. The term "base band frequencies" recently has come into use as a general term describing frequencies of this class.

When, however, the electrical quantities which are modified are changing periodically over a range of conditions, such as those produced by an alternating current, the signal frequencies resulting from the modulation are different from those in the originating medium and fall in the frequency range above and below the frequency of the unmodulated condition. The bands in which these frequencies fall are the well-known "upper side band" and "lower side band," and the frequency around which the bands are disposed is the "carrier" frequency. Regardless of the method of modulation, the side frequencies are displaced from the carrier by intervals equal to the signal frequencies or harmonics thereof.

The terms "modulation" and "carrier" came into general use when the first carrier and radiotelephone systems were being developed. The use of devices in which modulation changed the signal medium ante-

Essentially full text of paper 47-150, "Modulation in Communication," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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dated the use of modulation to change signals from one location in the frequency spectrum to another and, as a result, is not generally thought of as modulation. Similarly, the idea of a direct current being a carrier current with zero frequency is encountered even less frequently. Although these conceptions are sometimes helpful in a broad over-all consideration, present accepted practice considers as "carrier systems" only those systems in which the frequency being modulated is other than zero. Those systems in which the carrier is effectively a direct current are known as "direct current systems" in telegraph; as "voice" or "audio frequency systems" in telephony, and as "video systems" in television.

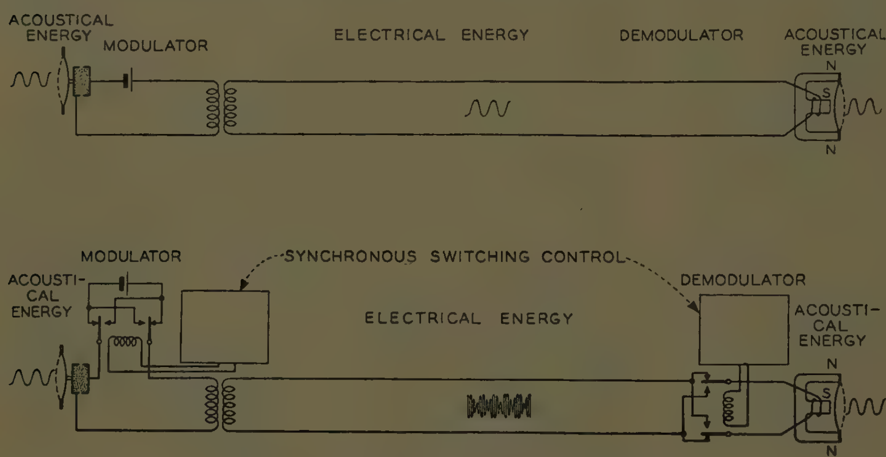


Figure 1. Possible telephone connections

A—Voice frequency telephone circuit
B—Carrier frequency telephone circuit

MODULATION IN THE TELEPHONE TRANSMITTER AND RECEIVER

In most telephone instruments the variation in resistance of the carbon granules in the transmitter in response to the impressed speech determines the value of a direct current. One arrangement used in supplying the current is indicated in Figure 1*A*. If this direct current were converted into an alternating current by the introduction of a pole changer as shown in Figure 1*B*, the result of impressed speech would be amplitude modulation of this alternating current. The signal message then would be carried by the upper and lower side bands of the frequency produced by the pole changer.

In the usual telephone receiver, a magnetic field produced by the signal currents interacts with the field of a permanent magnet to produce forces on the diaphragm which reproduce the speech. If the permanent magnet in the receiver were replaced by an electromagnet which was supplied with an appropriately phased alternating current of the same frequency as that supplied the transmitter by the pole changer, the receiver would reproduce the impressed speech from the signal side bands produced by modulation at the transmitter.

As an alternative to this arrangement, a pole changer could be introduced at the receiving end which, in effect, would rectify the a-c signal and then operate in the usual manner on the telephone receiver. This arrangement is indicated schematically in Figure 1*B*. The difference between the telephone system employing voice frequency transmission and that employing transmission over an a-c carrier for a single channel is merely the introduction of the appropriately phased pole changers at each end of the circuit.

TYPES OF SIGNALS

The type of modulation employed frequently depends upon the nature of the signals which must be transmitted. Two broad classes may be used—types with a limited and types with an unlimited number of conditions.

In the first category is the 2-condition type of signal used in most telegraph and supervisory circuits. Two condition signals, such as open or closed, marking or spacing, on or off, and positive or negative, may be designated as "yes or no" signals. Special codes with more than two conditions are sometimes desirable. The synchronizing signals in television transmission with three amplitudes or conditions are an example. Two of the amplitudes correspond to each of the extreme picture conditions of black and white, while the third is a higher amplitude.

The second category includes unaltered signals from a telephone, and those produced by scanning pictures for transmission over a telephotograph or television system. Here a wide range of finely graduated tones or conditions is necessary. As the extent to which fine gradations can be resolved or appreciated is limited, signals of the second category can be converted into signals of the first category. In this alteration a sufficient number of gradations must be retained to insure acceptable reproduction at the receiving end.

Another characteristic of signals which is important is the rate at which the different conditions need to be transmitted. This rate may be relatively slow, as in manual telegraph, or exceedingly rapid, as in the transmission of a television picture. The required rate of change determines the minimum frequency band width necessary for the signal transmission. The width of the required signal band may be altered significantly by changes in the form of signals to be transmitted. For example, the 32 characters of a teletypewriter might be represented by 32 gradations in amplitude of a current, and only one of these gradations would need to be

transmitted for each character. If, in order to differentiate with greater certainty between the different characters, it were found desirable to change to a 2-condition "yes or no" type of signal, a permutation code having five "yes or no" sequential conditions would be necessary to represent a total of 32 characters. Thus, to obtain greater certainty of correct recognition of conditions, the rate at which the different conditions must be transmitted has been increased fivefold, with a corresponding increase in the minimum band width required for the same speed of character transmission. In the same way the representation of the gradations in amplitude of speech by a "yes or no" code, such as is used in pulse code or pulse counting systems, requires a sevenfold increase in minimum signal band width where 128 gradations of amplitude are transmitted.

Signals which have been resolved into the "yes or no" type, with an accompanying change in the minimum band width required, do not necessarily represent the limiting extent to which signals can be changed to obtain greater certainty of correct reception. Further changes in signal types though not common sometimes are necessary. Such an instance is encountered in telegraphy where the practice has been occasionally to repeat messages.

MECHANISM OF MODULATION

Any mechanism which will produce the desired changes in conditions in response to signals may be employed for modulation. The variable frequency oscillator used in transmission testing work exemplifies two types of modulation by manual control. Frequency modulation may be accomplished by turning the frequency adjustment dial, and amplitude modulation by turning the output or volume control dial.

So long as the signaling speeds are low, mechanically controlled switches, commutators, relays, potentiometers, and variable capacitors may be used satisfactorily. For higher signaling speeds, variable impedance elements, such as vacuum tubes, rectifiers, and varistors, may be arranged to form networks. Some of the instrumentalities used for modulation are shown in Figure 2. The changes introduced by the modulating circuits may be gradual over all, or most, of the range, or may be abrupt. An effective design is usually one in which the character of change is abrupt and approximates a switch. In the analysis of such circuits it is often convenient to assume the elements to be replaced by equivalent switches capable of operation at the required speed.

Switching type modulators display interesting versa-

Figure 2. Instrumentalities used for modulation

tility. A simple switch can be an effective modulator—the telegraph key (Figure 3 *A*) being one example. Circuits with this abrupt control are not limited to on or off type of control but may be used with signals having an unlimited number of signal conditions. A switch, or its equivalent, arranged so that it closes on one polarity of a carrier current and opens on the opposite polarity, will serve as an efficient amplitude modulator for speech and other types of signals. One commonplace arrangement of this type is the varistor bridge modulator shown in Figure 3*B*. The switching action of the bridge-type modulator results from the variable impedance of the varistors forming the bridge. When the polarity of the carrier is in the direction in which the varistors conduct readily, the current flow causes the effective impedance to drop to quite low values, thus effectively placing a low impedance across the circuit. When the polarity is in the opposite direction, the impedance of the varistors is quite high, the impedance of the circuit is effectively high, and a negligible bridging effect corresponds to the open condition of the switch. The signal in this case is passed and suppressed alternately, and the resulting output contains, in addition to the signal, the amplitude-modulated double side bands of the carrier frequencies and its harmonics. As frequency- or phase-modulated signals may be developed from side bands originally created on an amplitude basis, the simple switch may be used for frequency modulation.

The ring or reversing switch-type modulator shown in Figure 3*C* also depends upon the variation in impedance of the varistors. The circuit is arranged so that on one polarity of the carrier one pair of diagonally opposite varistors is low in impedance and the other pair is high. Reversal of this condition for the opposite polarity furnishes the effective reversal of the polarity for transmission through the modulator. This pole changing type of modulator has the advantage of placing the signal carrier and output terminals in a conjugate relationship, thus effectively limiting the output to the modulation products.

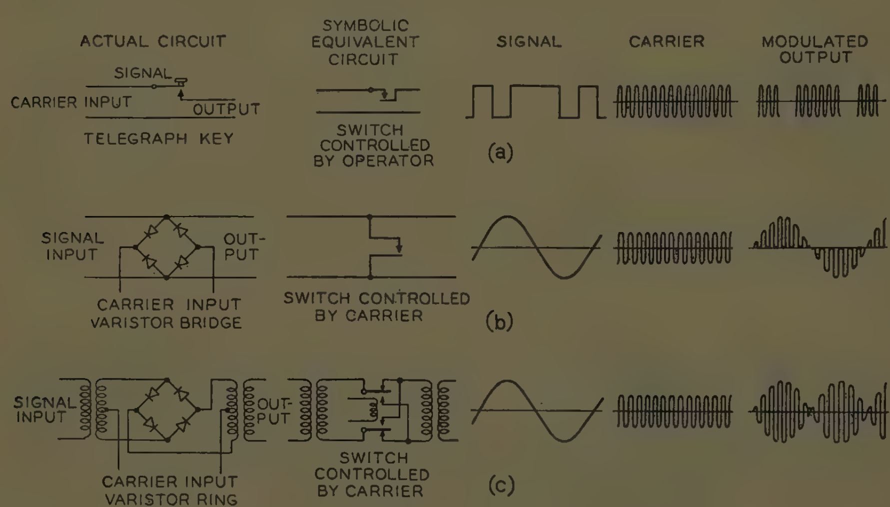


Figure 3. Illustrative modulation system

Two amplitude modulating switches, arranged with one switch open while the other is closed and vice versa, will permit signals from two separate channels to be connected to a line on a time division multiplex basis. If the switches are biased so that they are closed for a much shorter length of time than they are open, a number of such channels may be interleaved on a time division basis. The switching required for time division multiplex may be done with relays, mechanical commutators, special vacuum types with electric beam commutating, or with amplitude modulators employing varistors, crystals, or vacuum tubes to act as "gate" circuits under the control of switching currents.

Two switches under the control of "yes or no" signals may develop frequency shift modulation, if these switches are arranged so that a different frequency is connected to the circuit under each of the two signal conditions.

A switch, or a circuit equivalent to a switch, can be caused to generate pulses and, by proper control of the timing, the various forms of pulse modulation may be generated. In pulse position modulation, a pulse is generated once during each of a succession of fixed time intervals. The instant of generation within the interval is determined by the impressed signal. The usual arrangement is to have the operation retarded for one polarity and advanced for the other polarity of the signal, the degree of advancement or retardation being controlled by the amplitude of the signal.

It is an interesting fact that the output of a pulse position modulator represents a frequency or phase modulation of the switching frequency. The harmonics of this switching frequency which are generated by the abrupt switch operation also carry phase or frequency modulation, so that still another means of deriving frequency-modulated signals from a simple switching operation is available. The harmonics which are assumed to be used in this case, in other cases would represent unwanted modulation products which may be removed by filters, being above the wanted band.

MODULATION PRODUCTS

Unwanted signal or modulation products in the modulator output are not objectionable so long as

they can be removed by filters. However, in some cases the signal and carrier frequencies are so related that unwanted products may fall into the same band as the wanted products. Unwanted signal and carrier frequencies may be reduced greatly by the use of balanced ring-type modulators, but this does not eliminate those modulation products associated with harmonics of the carrier. As these arise from the abrupt switching action, removal would require that the switching operation be performed in such a manner that the current ratio corresponding to the transmission of the signal through the modulator would be a linear function of the instantaneous carrier magnitude. Modulators of this type are difficult to achieve, and for most situations, would have no significant advantage. Such a modulator would be a so-called pure product modulator, and the classical mathematical expressions for the product of the signal currents and a sine wave representing the carrier would be rigorously correct.

A rigorous mathematical analysis of the type of modulator with abrupt changes can be made by classical methods, if the carrier is represented by a Fourier series determined by the current ratio of the signal transmission through the modulator as a function of time. This quantity, when combined with the signal currents on a product basis, will give the output currents.

Such an analysis shows that a signal introduced into a switching type modulator circuit, in which the switching is controlled by a carrier, will produce side band modulation products associated with the fundamental carrier frequency which are essentially the same as those which would result from a pure product modulator supplied with the same signal and a pure sine wave of the carrier frequency. A quite different result would be obtained if the signal and carrier were interchanged. This results from the unwanted harmonics occasioned by the abrupt changes falling well above the wanted products in the first case and falling within the wanted band in the second case.

Although it is convenient to think of the carrier being modulated by the signal, the actual process is for the carrier to modulate the signal.

SIMILARITIES BETWEEN DIFFERENT TYPES OF MODULATION

The fact that the more important types of modulation can be produced by somewhat similar circuits indicates that the various types are related rather closely. There are certain other interesting relationships which may be noted.

About 30 years ago Carson demonstrated that either of the two side bands resulting from the amplitude modulation of a carrier conveyed all of the information present in the signal, and that it should be sufficient to transmit only one of these side bands over the communication system. This has resulted in the wide use of single side band transmission where two channels can be transmitted within the band which would be occupied by the double side band signal corresponding to one channel. The manner in which such a 2-channel system could be set up is indicated schematically in Figure 4*A*. This commonly is called frequency division.

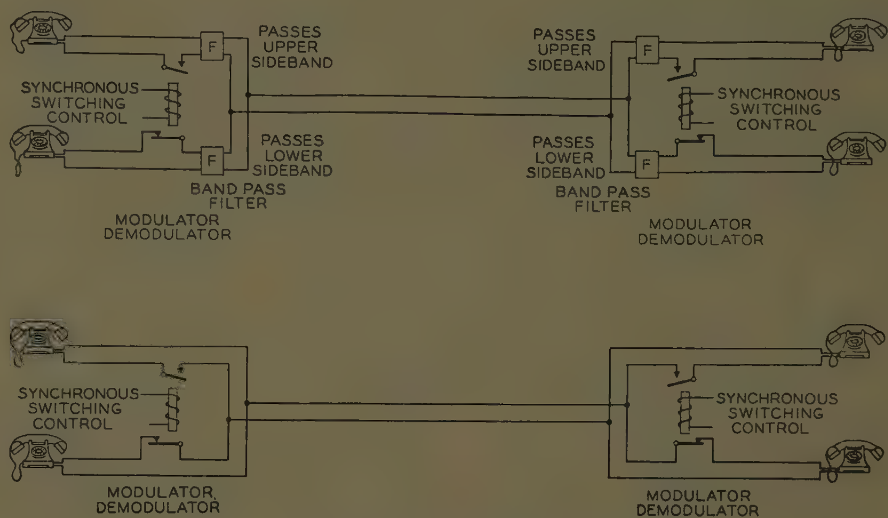


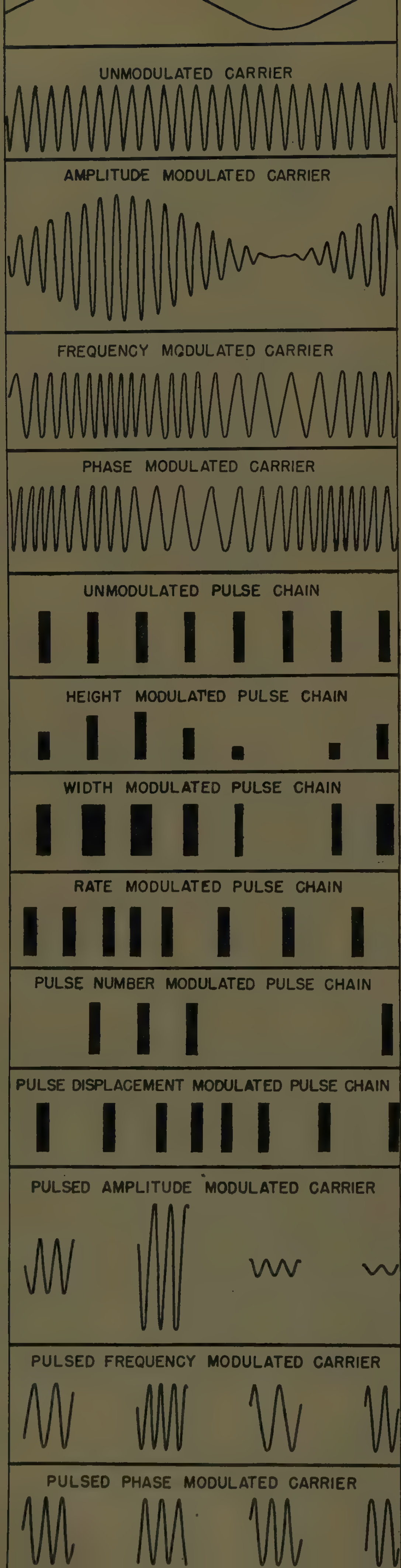
Figure 4. Comparison of 2-channel carrier systems

A—Amplitude modulation: single-side-band frequency division transmission
B—Amplitude modulation: time division transmission

TIME DIVISION

Two channels also could be obtained by the time division method with amplitude modulation. The schematic arrangement for such a time division system is shown on Figure 4*B*. Used separately, each of these time division channels does not differ from a double side band amplitude modulation system with a carrier frequency determined by the switching rate. When they are combined for transmission over the line, the frequencies of the two channels fall into the same band. They are, however, so related in phase that they may be separated at the receiving end on a time division basis.

As is indicated on the chart, the elements of the two types of 2-channel systems may be identical except that in the frequency division case single side band filters are introduced to accomplish division by this means.



ADVANTAGE OF SINGLE SIDE BAND

One factor which has occasioned the use in telephony of single side band systems in preference to time division amplitude modulating systems is the extreme precision in attentuation and phase response required in time division to keep interchannel cross talk at acceptable values. With "yes or no" telegraph-type signals, higher values of interchannel interference are permissible without serious reaction. Thus, time division systems have been used widely in telegraphy. Time division also is coming into use in telephony when speech is converted to pulse position, pulse code, or similar signals.

COMPARISON OF MODULATION SYSTEMS

The determination of the desirable type of modulation or transmission system depends upon many interrelated factors which vary widely with the condition of application. Some of these are

1. Length of system—more complex terminal or modulating system can be justified for long wire systems.
2. Relative availability of frequency space.
3. Variation of cost of transmission system with frequency band width.
4. Type of signals.
5. Ratio of minimum required frequency band to that practically necessary allowing for filters and frequency stability.
6. Desired fidelity or performance.
7. Nature of transmitting medium.

Each type of modulating system in general use has some feature which recommends its use under some conditions and not under others.

For most systems of modulation, improved performance may be gained by utilizing a wider frequency band. This improvement generally is reduced when high values of noise or interference are present. With certain types of noise there is a tendency toward encountering this limitation more frequently as the frequency band is widened.

One outstanding exception to the rule of improvement accompanying increased band width is a single side band transmission system, when an improvement of about nine decibels with respect to a double side band amplitude-modulated system may be obtained. This approximates what would be obtained by the use of frequency modulation employing $2^1/_2$ times the band width of a single side band system.

The qualifications which must accompany even these simple generalizations are an indication of the difficulty of attempting to determine the appropriate form of modulation for a given set of conditions without careful study.

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ABSTRACTS... OF AIEE TECHNICAL PROGRAM PAPERS

Air Transportation

47-214-ACO—Electricity Aloft; *T. J. Martin (M '45). 35 cents.* The use of electric power on aircraft started with Tissandier's motor-driven balloon, in 1882. Since the early days of the airplane, when electricity was used only for ignition, electricity has grown in importance until today it is nearly as essential to the flight of an airplane as is the gasoline which furnishes power to its engines. This paper summarizes the developments in the use of electric power in aircraft, from the early days of man-carrying balloons. Some of the equipment is described briefly, and predictions are made concerning the future of aircraft electric systems.

47-222—Aircraft Electric Power Protective Systems; *B. O. Austin (M '43). 25 cents.* The paper extends further the developments outlined in the author's paper "Control and Protection of Aircraft D-C Power Systems" (*EE, July '46, pp 741–5*). Progress described includes dual contactors, a novel overvoltage relay remarkably free from nuisance trips, a new scheme to make the protective system independent of the battery, a novel form of relay for balanced differential-current protection, both for generators and feeders, and a positive means for avoiding generator polarity reversal. Test results, oscillograms, and performance curves are presented showing the performance of the system and equipment on an actual 4-generator mock-up.

47-223-ACO—Aircraft Electric System Testing; *P. H. Merriman. 20 cents.* More satisfactory solutions to aircraft electric system design problems are possible through carefully planned testing. The part which testing can play in meeting the increasing demands on the systems and in combatting the causes of service failures is emphasized. Two main points are made:

1. Testing should be performed simultaneously with design, and under conditions which truly simulate all operating conditions.

2. Three main phases of the test program are recognized: components, systems, and flight, in which all possible work is done under laboratory conditions, and flight testing is reduced to the simplest possible terms.

The writer has drawn on some ten years' experience in military and commercial aircraft electrical work in indicating how electric system shortcomings are preventable in the design stage through this approach, and how this may be achieved without heavy sacrifices in cost and time.

47-225—Power and Control Systems for Aircraft Window Deicing; *C. L. Mershon (A '47). 20 cents.* The problem of preventing the formation of ice and fog on aircraft windows always has presented difficulties. Although various methods of window heating are being used, none, in general, is completely effective for all flying conditions. A new transparent electrically conductive coating has been developed which can be applied to the surface of the glass of a window to form a heating element which promises to be far superior to any existing type of window heater. The effectiveness of such a heater depends greatly upon the power and control systems with which it is used. The author has attempted to analyze some of the power and control problems peculiar to this type of window heater. Various window heating control circuits and the equipment used in such circuits are discussed.

TECHNICAL PAPERS previewed in this section will be presented at the AIEE Middle Eastern District meeting, Dayton, Ohio, September 23–25, 1947, and will be distributed in advance pamphlet form as soon as they become available. Members may obtain copies by mail from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstracts; or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk. Prices of copies to nonmembers will be twice those for members, less five cents for mailed copies.

MAIL ORDERS will be filled as pamphlets become available.

ABSTRACTS are prepared by the authors of the papers and approved by the technical program committee.

47-233—Using Air-borne Radar to Increase Air Line Safety; *R. W. Ayer. 30 cents.* Minor but significant modifications to existing *X*-band air-borne radar types have made it practical for the pilot himself to use radar for avoiding collisions with terrain, for emergency negotiation of "letdowns" over terrain surrounded by hills, for avoidance of dangerous areas of precipitation (thunderstorms, freezing rain, hail, and snow) and its associated turbulence whether flying over land or water, and as "weatherproof" supplementary navigational aid where water–land or other "contrast" exists in the echoes. From the same modified *X*-band air-borne radar against ground responders ("racons" or "beacons"), a simplified navigation system has resulted which improves the precision of flying in areas of high traffic density, provides a simple means of making multidirectional "low approaches" to an airport under conditions of low visibility, and provides a weatherproof stand-by enroute navigation system.

47-234-ACO—Landing Through Overcast. *W. T. Harding (A '44). 20 cents.* In an effort to secure equipment and to establish operating procedures suitable for landing of aircraft under extremely adverse weather conditions, the Army Air Forces, Bureau of Aeronautics, Navy Department, and civil agencies interested in commercial operation of aircraft have joined forces in operating the Landing Aids Experiment Station at Arcata, Calif. The Arcata project, which has been in operation slightly over a year, already has demonstrated that aircraft operations under weather conditions rated as zero ceiling with daytime visibility of one-eighth mile are perfectly feasible and safe, provided the proper landing aids are made available and provided pilot personnel are trained in their use. The application of these principles may require the abandonment of some existing airports, if the ultimate all-weather operation is to be realized.

47-235—Airport Runway and Approach Lighting; *G. M. Kevern (A '40). 20 cents.* Rapid and extensive changes in airport lighting have been made within the last ten years. The necessity for providing elevated high intensity runway and approach lights as an aid during low visibility conditions, both day and night, generally has been recognized. With the advent of adequate runway lighting, boundary lights and floodlights (for runways) have become unnecessary. The provision of high intensity runway and approach lights of the latest type, results in a 10,000 per cent increase in power consumption per runway. This power increase, together with the necessity for providing brightness as low as one per cent of normal, has resulted in radical changes in the electric distribution system.

47-236—High Altitude Flashover and Corona Correction on Small Ceramic Bushings; *W. W. Pendleton (M '43). 20 cents.* The use of modern radar equipment in aircraft has introduced high voltages which have resulted in corona and flashover problems in connection with the ceramic bushings associated with radar components. A marked improvement in corona voltage and flashover voltage for small ceramic bushings has been obtained by the use of semiconducting coatings. The results cover both a-c and d-c behavior for several sizes of solder-seal bushings. A sensitive oscilloscopic method detects disturbances at voltage gradients where the ionization-by-collision process begins. These gradients, far below the visual corona points, are calculated from graphical maps of the dielectric fields associated with the bushings. A method also is discussed whereby flashover data may be correlated with bushing shape and size.

Air Matériel Command photo

Guided missile developed by Wright Field Laboratories in Dayton, Ohio, scene of AIEE Middle Eastern District meeting

Electric Machinery

47-206—The "Copperspun" Squirrel-Cage Rotor; *G. R. Anderson (M'29). 20 cents.* The simplicity and rugged construction of the squirrel-cage winding of the induction motor has contributed in a large measure to making it the most widely used of all motors. This paper describes the method of fabricating a one piece squirrel-cage winding of copper or copper alloy, and outlines the factors that must be considered in the design of apparatus and the technique of casting. It gives comparative data between the use of copper and aluminum as related to the performance of the motor.

47-208—Calculation of Slot Constants; *A. F. Puchstein (M'27). 30 cents.* To calculate the design and performance of induction motors, the leakage reactance must be known. This usually is divided into the four parts: slot, zigzag, end-connection, and differential leakages. To compute the first of these, the slot constants of stator and rotor must be known. This paper gives the formulas and derivations for full and partly full circular, elliptical, rectangular, and trapezoidal slots. Special attention is paid to rectangular and trapezoidal slots with one or two semicircular ends. Principles outlined may be used for investigating other slot shapes.

47-209—The Air Gap Reactance of Polyphase Machines; *P. L. Alger (F'30), H. R. West (M'28). 40 cents.* This paper presents some new formulas for the differential leakage reactance of distributed polyphase windings, which take into account the slot openings. The formulas have been derived independently by the "overlap" and "differential" methods of analysis. The results show that the presence of slot openings decreases the differential leakage reactance more rapidly than the magnetizing reactance, so that the new formulas give lower values of leakage than those previously presented. The formulas are of particular interest in the design of induction motors and voltage regulators.

47-212—Reactances of Induction Motors; *T. C. Lloyd (M'46), V. F. Giusti (A'44), Sheldon S. L. Chang (Student Member). 35 cents.* This paper shows a method of calculating the leakage reactances of polyphase induction motors, using permeances of the paths for slot, zigzag, and end leakage fluxes. The method is set up to be readily applicable to concentric-winding single phase motors, using some of the same basic factors. Results are compared with those obtained by a number of other published methods, and differences are discussed. Numerical work illustrating the method makes use of a sample design prepared by the committee.

***47-213-APO—Test Results of Motor Used for Leakage Reactance Calculations;** *A. L. Poliquin (A' 46), A. S. Bickham (M'43).* This paper presents results of impedance test made on a 2-horsepower 220/-440-volt 60-cycle 1,750-rpm 3-phase 40-degrees-centigrade continuous-duty class-*A* motor, in accordance with the "AIEE Test Code for Polyphase M-chines." The leakage reactance of this motor had been calculated previously from dimensions and data furnished by the manufacturer. Additional test data are presented for the purpose of supplying complete test information.

47-217—A Variable Speed Constant-Frequency Generator; *C. S. Roys (M'45), Joseph Nader (A'43), Melvin Spotts. 20 cents.* Starting with the theory of operation of a-c commutator machines, it is shown how a single or polyphase generator can be designed whose frequency is essentially independent of speed. Among the principal topics discussed are generated voltage equations, conditions for self-excitation, armature reaction and transformer voltage compensation, commutation, regulation, parallel operation, compounding, and the operation as a motor.

47-219—Performance Calculations on Shaded-Pole Motors; *P. H. Trickey (F'47). 30 cents.* In 1936, the writer presented a paper on "An Analysis of the Shaded Pole Motor" *(EE, Sept '36, pp 1007–14)* giving the fundamental circuit analysis and deriving the equations for currents and torque at standstill condition. This paper derives the equations for running conditions, and presents a calculation sheet. Friction, windage, and odd frequency iron losses are subtracted from the gross output, and fundamental frequency iron loss is added to the input by means of an inphase component of current. An equivalent circuit is shown. The calculation sheet also gives a short-cut method for current and watts input, plus a check method of output from input minus losses. With the currents obtained on this sheet, the vector equations from the original paper may be used as a check on the starting torque.

* Price to be announced.

47-220—A Design Method for Capacitor Start Motors; *Sheldon S. L. Chang (Student Member). 25 cents.* In capacitor-start induction run motors, the main winding usually is fixed by the rating of the motor on the basis of required maximum torque. The starting winding is designed to meet the following conditions:

1. The motor should have specified starting torque.
2. This starting torque should be maintained at least to the speed where the switch operates.
3. The voltage across the capacitor during the starting and accelerating period should not exceed a certain value.
4. The motor should start without excessive vibration.
5. Meeting all the foregoing conditions, the capacitor used should be of a standardized size and should be as small as possible.

The foregoing conditions are discussed theoretically and are put into a set of about 30 sheets of universal curves covering practically all possible instances. With the help of these curves, the work of designing a starting winding to meet the foregoing conditions is reduced to a relatively simple process. In addition, certain trends and interrelations are shown by these curves which are not so obviously apparent by ordinary calculations.

47-221—Impedance Relationships of the Adjustable Speed A-C Brush Shifting Motor; *Fred Baumann. 20 cents.* A new and simple method of calculating the performance of the Schrage-type motor by equivalent circuit is presented.

47-229—A High Precision Dynamometer for Small Motor Measurements; *J. E. Duff (M'47). 20 cents.* An important item of laboratory equipment for engineering departments interested in the design of small shaded-pole induction motors is a dynamometer of sufficient sensitivity to measure accurately those characteristics of such motors that cannot be computed accurately in their design. This paper describes the design and principles of operation of such a dynamometer. A method of reducing trunnion bearing friction by means of a rotating bearing race system is explained, and the inherent advantages of a dynamometer built around a shaded-pole induction motor and supplied with variable frequency power are analyzed. A brief appendix covering the derivation of a convenient torque scale calibration which yields power directly by multiplying the indicator deflection by revolutions per minute also is included.

47-230—The Theory and Application of Surge Comparison Testing Equipment to

Fractional Horsepower A-C Stator Windings; *Lloyd W. Buchanan (A '38). 20 cents.* This paper describes the application of a surge comparison test to fractional horsepower windings. This test subjects the windings of two motors to a voltage surge of steep wave front and short duration, and compares the two windings by recording the voltage across each winding on an oscilloscope. The voltage distribution in the windings is recorded, and an analysis is made of the voltages to which insulation at different points of the winding is subjected. The breakdown of insulation resulting from application of a surge voltage is compared with that of a 60-cycle voltage. Previous studies have pertained mainly to detection of short-circuited turns or wrong number of turns in 3-phase and large machines. These tests are here combined with additional tests into a quick and accurate procedure to include additional information relative to quality and accuracy of winding.

47-231-ACO—The Design and Application of Hermetic Motors; *F. L. Slade. 20 cents.* This paper describes the requirements in sealing an a-c motor in a housing with a refrigeration compressor, with the motor exposed to refrigerant and oil. It is pointed out that the performance characteristics of the motor need not differ from those of a conventional motor for compressor drive, but special materials are required. Special manufacturing and handling processes are needed to keep the parts free of rust, corrosion, or foreign materials. Overload and starting relays are discussed with a comparison of different types.

Instruments and Measurements

47-216—A Capacitance-Type Fuel-Measurement System for Aircraft; *D. B. Pearson (A '41). 20 cents.* The trend in the field of fuel-quantity measurement in aircraft is now towards the capacitance-type fuel gauge. The chief reasons for the increasing interest in gauges of this type are

1. The desire to obtain a measure of fuel quantity in terms of pounds rather than gallons.
2. The relatively simple manner by which totalized indication may be obtained.
3. The absence of moving parts in the fuel tank.

A brief general discussion of fuel measurement by the capacitance method and a more detailed description of a specific measurement system are included in this paper. The major problems encountered and solved during the development of this measurement system are described, and information on operating performance is presented.

47-226—Direct-Coupled Oscillograph Amplifier; *D. R. Christian (A '47). 20 cents.* The characteristics of a magnetic pen motor never have been fully realized when used with capacity-coupled amplifiers. This paper describes a stabilized direct-coupled amplifier developed for use with the magnetic-pen motor recorder. Included in the treatment of the subject matter are the general requirements of such an amplifier, an explanation of the circuits involved, description of the characteristics of the amplifier, and its application.

47-227-ACO—A Calorimetric Method for Direct Measurement of Plate Dissipation; *Ralph T. Squier. 20 cents.* Because of the characteristics of the circuit used and its effect on the wave form of tube voltage and current, the electrical measurements needed for the calculation of the plate dissipation in electronic tubes could not be made by the use of electrical measuring instruments readily available. A more fundamental instrument was indicated, such as the calorimeter. An analysis is made of the discriminator section of an amplifier circuit, and the difficulties encountered in determining plate dissipation. A description of the construction and operation of the calorimeter used is included, as well as the results of tests made on standard vacuum tubes.

47-215—Electric Drive for Aircraft; *George C. Crom. 25 cents.* The use of large amounts of power in aircraft becomes a power-handling problem, and electric transmission, from the turbines mounted in the fuselage to the propellers on the winds, has the same advantages as handling very large amounts of power in industry. The advantages of electric power transmission are discussed, principally, flexibility, reliability, ability to shut down prime movers, and lessened drag. Also the disadvantages, principally—weight. An outline of an acceptable airplane and the calculation of fuel savings resulting from electric operation of a given flight plan are given, showing that it is possible to save enough fuel to cancel out the extra weight of the electric drive. Also a discussion of weights of apparatus is given.

47-207-ACO—Physical Concept of Leakage Reactance; *J. H. Kuhlmann (M '27). 20 cents.* Electric circuits usually can be designed and constructed so that the current will follow definitely defined paths. Leakage currents easily can be held to the order of 10^{-12} ampere or even smaller, and their effect upon the performance of electric machinery can be neglected. To confine magnetic fluxes to prescribed paths is a very much more difficult problem, mainly because there is no true magnetic insulator. The magnetic flux that leaks from the prescribed path is usually of such magnitude that its effect upon electric machine performance cannot be neglected. The paper presents the basic considerations underlying the methods of calculating the leakage flux and shows how the effect of the leakage flux in a-c magnetic circuits can be expressed as a leakage reactance.

47-218—The Hysteresis Motor—Advances Which Permit Economical Fractional Horsepower Ratings; *Herbert C. Rotors (M '32). 35 cents.* The theory of the development of torque in a hysteresis motor is analyzed from both the hysteresis lag angle and total loop energy points of view. A new development, comprising the use of a closed-slot stator in co-operation with a hysteresis rotor, which permits building hysteresis motors of high power output at high efficiency, is explained qualitatively and supplemented by considerable quantitative experimental data. A new method of stator construction, permitting the use of closed-slot stator laminations assembled on a mandrel with nonmagnetic bearing supporting spiders, wound externally in either a d-c type of armature winding machine or with form-wound coils, impregnated with a thermosetting resin and baked to form a unitary structure, is described. The electrical design of the machine is covered and quantitative data on both design details and operating characteristics are given on several models.

47-211—Some Phases of Calculation of Leakage Reactance of Induction Motors; *W. H. Formhals (M '44), M. M. Liwschitz (M '39). 25 cents.* The leakage reactances of stator and rotor determine the performance of the induction motor. This explains why the designers of induction motors are so eager to improve the methods of calculation of these reactances. Considerable progress in this respect has been made during the past years. This paper discusses some difficulties in the calculation of leakage reactance which make a theoretically accurate method of calculation tedious and, therefore, lead the designer to use a "practical" method of calculation corrected by constants gained from tests. The topics discussed are influence of slot openings on differential leakage, influence of skewing on differential leakage, influence of saturation of leakage paths on slot and differential leakage, and influence of aluminum film of the rotor on the leakage.

47-210—Leakage Reactance of the Squirrel-Cage Rotor With Respect to the Stator Harmonics and the Equivalent Circuit of the Induction Motor; *M. M. Liwschitz (M '39). 20 cents.* The leakage reactance of the rotor usually is considered only with respect to the main wave of the stator which produces the useful torque of the machine. However, a squirrel-cage rotor reacts also to the harmonics of the stator, thereby producing parasitic torques. In this paper, the leakage reactance of a squirrel-cage rotor with respect to the individual stator harmonics is treated, and formulas for its calculation are given. Further, the complete equivalent circuit of the induction motor is derived which yields the resultant torque of the machine, that is, the torque produced by the main wave as well as by the harmonics. Only asynchronous torques are considered. Synchronous cusps are beyond the scope of this paper.

INSTITUTE ACTIVITIES

Dayton Meeting to Feature Visit to Wright Field

An interesting and varied program has been scheduled for the Middle Eastern District meeting which will be held in Dayton, Ohio, September 23–25, 1947. Aircraft applications will be stressed, and in keeping with this plan, an inspection trip to Wright Field is among the events scheduled on the program. A wide range of papers in the electric machinery field also been has cheduled. The meeting program and abstracts of the papers to be presented appear elsewhere in this issue.

ENTERTAINMENT

A stag smoker will be held at the Engineers' Club on Tuesday, September 23, 1947, at 7:30 p.m. Tickets are $2.75, which includes entertainment and a light lunch and refreshments served buffet style.

The banquet is scheduled for Wednesday, September 24, 1947, at 6:30 p.m. in the ballroom of the Dayton Biltmore Hotel. M. H. Wagner, Sr. (F '30) president of the Wagner-Smith Company will be the toastmaster, and Doctor William E. Wickenden will be the principal speaker. Special invitation is extended to women. Dress will be informal. Tickets are $4.50. An entertaining program has been planned.

A luncheon, card party, and fashion show is arranged for the women for Tuesday, September 23, 1947, at 1:15 p.m., at Rike-Kumler's dining room. Tickets are $2.00.

A special sight-seeing tour of local points of interest will be available for the women at 1:30 p.m., Wednesday, September 24, 1947, without charge. This will include a tour of McCall's pattern department.

Facilities will be available in the city for those wishing to play golf or tennis.

INSPECTION TRIPS

There will be four inspection trips conducted in parallel Wednesday afternoon, September 24, 1947. These four trips all will start at 1:30 p.m.

1. McCall Corporation—pattern making and publication of many well-known periodicals.

2. Delco Products Division, General Motors Corporation—electric motors and automotive accessories.

3. National Cash Register Company—cash registers and business machines.

4. Dayton Rubber and Manufacturing Company—rubber products, including tires, tubes, belts, and other industrial items.

Busses will be provided, and tickets will be 25 cents to cover cost of transportation.

On Thursday, September 25, 1947, there will be two inspection trips to Wright Field, one starting at 9:30 a.m. and the second starting at 1:00 p.m. There is a definite limitation on numbers for each Wright Field trip. Local members (those who have the opportunity of visiting the field at other times) will be requested to defer to out-of-town registrants in case more than 200 desire to take either trip. Tickets will be 50 cents and admission to the field will be by chartered bus only. No cameras will be permitted.

PROOF OF CITIZENSHIP NEEDED

It will be necessary for those desiring to attend either of the Wright Field inspection trips to produce evidence of citizenship at time of registration (United States or Canada) in order to be admitted to Wright Field. A birth certificate is the best and least contestible proof of citizenship.

Front view of the full scale Republic JB-2 robot bomb, mounted inverted, being inspected before testing in the 22-foot wind tunnel at the Air Technical Service Command, Wright Field, Ohio

(Below). View showing two of the wind tunnels at Wright Field. The one on the left is the 20-foot-wide horizontal tunnel, and the one in the right foreground is the 80-foot-high vertical wind tunnel

The members of the District meeting committee are

R. C. Abbott	R. S. Hull
W. R. Appleman	J. O. Lang
W. A. Barden	E. C. Merkle
E. J. Bates	R. E. Mumma
C. T. Button	J. M. Rodgers
H. E. Deardorff	C. H. Spitler
W. A. Dynes	H. S. Starbuck
J. L. Fritz, *general chairman*	G. I. F. Theriault
W. M. Gallagher	M. H. Wagner, *senior honorary chairman*
J. W. Gehrke	M. H. Wagner, Jr.
G. B. Hamm, *secretary*	Alan Watton
C. Higgins	R. Zimmerman
F. S. Himebrook	Mrs. W. A. Dynes
R. W. Hommel	Mrs. G. I. F. Theriault

ADVANCE REGISTRATION

Advance registration cards are being mailed to members. They should be filled in and returned promptly. This will save time at the registration desk. No registration fee will be charged for members, Student Members or immediate families of

(*continued on page 930*)

Middle Eastern District Meeting Program, Dayton, Ohio, September 23-25, 1947

Monday, September 22

10:00 a.m. District Executive Committee Meeting

4:00 p.m. Advance Registration

Tuesday, September 23

8:15 a.m. Registration

9:00 a.m. Opening General Session

L. J. Fritz, presiding

Address of welcome by the Honorable **Edward Breen**, mayor of Dayton, Ohio

Response by **George W. Bower**, vice-president, District 2. AIEE announcements

10:00 a.m. Electric Machinery—Leakage Reactance

W. R. Hough, presiding

47-207-ACO.* THE PHYSICAL CONCEPT OF LEAKAGE REACTANCE. **J. H. Kuhlmann**, University of Minnesota

47-208. CALCULATION OF SLOT CONSTANTS. **A. F. Puchstein**, The Jeffrey Manufacturing Company

CP.** END TURN LEAKAGE REACTANCE OF A POLYPHASE INDUCTION MOTOR WINDING. **E. C. Barnes**, Reliance Electric and Engineering Company

47-209. THE AIR GAP REACTANCE OF POLYPHASE MACHINES. **P. L. Alger, H. R. West**, General Electric Company

1:15 p.m. Women's Luncheon, Fashion Show, and Card Party

Dining room, fifth floor, Rike-Kumler Company

2:00 p.m. Electric Machinery—Leakage Reactance (continued)

J. L. Hamilton, presiding

47-210. LEAKAGE REACTANCE OF THE SQUIRREL CAGE ROTOR WITH RESPECT TO THE STATOR HARMONICS AND THE EQUIVALENT CIRCUIT OF THE INDUCTION MOTOR. **M. M. Liwschitz**, Polytechnic Institute of Brooklyn

47-211. SOME PHASES OF CALCULATION OF LEAKAGE REACTANCE OF INDUCTION MOTORS. **W. H. Formhals, M. M. Liwschitz**, Polytechnic Institute of Brooklyn

47-212. REACTANCES OF INDUCTION MOTORS. **T. C. Lloyd, V. Guisti, S. S. L. Chang**, Robbins and Myers, Inc.

47-213-ACO. TEST RESULTS OF MOTOR USED FOR LEAKAGE REACTANCE CALCULATIONS. **A. L. Poliquin**, The Master Electric Company; **A. S. Bickham**, Whirl-A-Way Motors, Inc.

CP.** INFORMAL DISCUSSION OF CALCULATIONS OF LEAKAGE REACTANCE OF SAMPLE MOTOR.

E. C. Barnes, Reliance Electric and Engineering Company

B. M. Cain, General Electric Company

W. H. Formhals, Westinghouse Electric Corporation

T. C. Lloyd, Robbins and Myers, Inc.

2:00 p.m. Air Transportation—General Development

W. T. Harding, presiding

47-214-ACO. ELECTRICITY ALOFT. **T. J. Martin**, Jack and Heintz Precision Industries, Inc.

CP.** A CONSTANT SPEED DRIVE FOR AIRCRAFT ALTERNATORS. **L. H. Schuette, R. Chrzanowski**, Sundstrand Machine Tool Corporation

47-215. ELECTRIC DRIVE FOR AIRCRAFT. **G. C. Crom**, Air Matériel Command, Wright Field

47-216. A CAPACITANCE-TYPE FUEL MEASUREMENT SYSTEM FOR AIRCRAFT. **D. B. Pearson**, General Electric Company

47-217. A VARIABLE-SPEED CONSTANT-FREQUENCY GENERATOR. **C. S. Roys**, Syracuse University; **J. Nader, M. Spotts**, Eicor, Inc.

7:30 p.m. Smoker

Entertainment, buffet lunch, Engineers Club of Dayton

—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—ABSTRACTS of most papers appear on pages 925–7 of this issue.

—PRICES and instructions for procuring advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the technical program committee ultimately will be published in PROCEEDINGS and TRANSACTIONS; essential substance of many will appear in ELECTRICAL ENGINEERING.

Wednesday, September 24

9:30 a.m. Electric Machinery—Motor Design

C. G. Veinott, presiding

47-218. THE HYSTERESIS MOTOR—ADVANCES WHICH PERMIT ECONOMICAL FRACTIONAL HORSEPOWER RATINGS. **H. C. Roters**, Fairchild Camera and Instrument Corporation

47-219. PERFORMANCE CALCULATIONS ON SHADED POLE MOTORS. **P. H. Trickey**, Diehl Manufacturing Company

CP.** DESIGN OF FRACTIONAL HORSEPOWER D-C MOTORS. **O. M. Swain**, Westinghouse Electric Corporation

47-220. A DESIGN METHOD FOR CAPACITOR START MOTORS. **S. S. L. Chang**, Robbins and Myers, Inc.

47-221. IMPEDANCE RELATIONSHIPS OF THE ADJUSTABLE SPEED A-C BRUSH SHIFTING MOTOR. **F. W. Baumann**, General Electric Company

9:30 a.m. Air Transportation—Current Projects

K. R. Smythe, presiding

47-222. AIRCRAFT ELECTRIC POWER PROTECTIVE SYSTEMS. **B. O. Austin**, Westinghouse Electric Corporation

47-223-ACO. AIRCRAFT ELECTRICAL SYSTEM TESTING. **P. H. Merriman**, G. L. Martin Corporation

CP**. INVERTERS AND INVERTER SYSTEMS FOR AIRCRAFT. **S. J. Zak**, Engineering Division, Wright Field

CP.** ELECTRICAL DEICING OF AIRCRAFT PROPELLERS. **J. H. Sheets, E. J. Sand**, Curtiss-Wright Corporation

47-225. CONTROL AND POWER SYSTEMS FOR AIRCRAFT WINDOW DEICING. **C. L. Mershon**, Westinghouse Electric Corporation

9:30 a.m. Industrial Electronics

W. C. Osterbrock, presiding

CP.** NEW DEVELOPMENTS OF ELECTRONIC EQUIPMENT FOR THE RUBBER INDUSTRY. **B. J. Dalton**, General Electric Company

47-226. DIRECT-COUPLED OSCILLOGRAPH AMPLIFIER. **D. R. Christian**, The Brush Development Company

47-227-ACO.* A CALORIMETRIC METHOD FOR DIRECT MEASUREMENT OF PLATE DISSIPATION AND LOADS. **R. Squier**, Minneapolis-Honeywell Regulator Company

CP**. CURRENT DISTRIBUTION IN SEMICONDUCTOR HEATED BY HIGH FREQUENCY CURRENTS. **F. C. Weimer**, The Ohio State University

CP.** A THYRATRON-CONTROLLED AUTOMATIC WELDING HEAD. **R. J. La Plante, G. H. Fett**, The University of Illinois

CP.** TIMING CIRCUITS IN RESISTANCE WELDING CONTROLS. **B. Sussman**, General Electric Company

12:00 noon. Luncheon Meeting of Student Branch Counselors

1:30 p.m. Inspection Trips

National Cash Register Company

McCall Corporation

Delco Products Division of General Motors Corporation

Dayton Rubber Manufacturing Company

1:30 p.m. Special Sight-Seeing Trip for Women

Includes inspection trip through the pattern department, McCall Corporation

6:30 p.m. Banquet

Ballroom, Dayton Biltmore Hotel

WARNING!

Evidence of citizenship is required for Wright Field inspection trip

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*ACO: Advance copies only available; not intended for publication in *TRANSACTIONS*.

**CP: Conference paper; no advance copies are available; not intended for publication in *TRANSACTIONS*.

(Middle Eastern District Meeting Program, continued)

Thursday, September 25

9:00 a.m. Electric Machinery—Processing and Testing

W. R. Appleman, presiding

47-206. THE "COPPERSPUN" SQUIRREL CAGE ROTOR. **G. R. Anderson,** Fairbanks, Morse and Company

47-229. A HIGH PRECISION DYNAMOMETER FOR SMALL MOTOR MEASUREMENTS. **J. E. Duff,** The Hoover Company

CP.** EXPEDITING AND IMPROVING HEAT RUNS WITH A MULTIPOINT TEMPERATURE RECORDER. **J. L. Fuller,** Reliance Electric and Engineering Company

47-230. THE THEORY AND APPLICATION OF SURGE COMPARISON TESTING EQUIPMENT TO FRACTIONAL HORSEPOWER A-C STATOR WINDINGS. **L. W. Buchanan,** Westinghouse Electric Corporation

47-231-ACO. THE DESIGN AND APPLICATION OF HERMETIC MOTORS. **F. L. Slade,** Century Electric Company

9:00 a.m. Air Transportation—Air Traffic Control Equipment

J. D. Miner, presiding

CP**. AIR TRAFFIC CONTROL. **C. W. Carmody,** Civil Aeronautics Authority

47-233. USING AIR-BORNE RADAR TO INCREASE AIRLINE SAFETY. **R. W. Ayer,** American Airlines, Inc.

47-234-ACO. LANDING THROUGH OVERCAST. **W. T. Harding,** Equipment Laboratory, Wright Field

47-235. AIRPORT RUNWAY AND APPROACH LIGHTING. **G. M. Kevern,** Air Matériel Command, Wright Field.

47-236. HIGH ALTITUDE FLASHOVER AND CORONA CORRECTION ON SMALL CERAMIC BUSHINGS. **W. W. Pendleton,** Westinghouse Electric Corporation

9:30 a.m. First Inspection Trip to Wright Field

1:00 p.m. Second Inspection Trip to Wright Field

(continued from page 928)

members. A registration fee of $2.00 will be charged all nonmembers.

HOTEL ACCOMMODATIONS

The hotel committee has been fortunate in securing block reservations at the following hotels, all of which are within a short distance of the meeting headquarters:

Hotel	Rates Double	Rates Single
Dayton Biltmore Hotel (meeting headquarters)	$6.00 up	$4.00 up
Van Cleve Hotel	6.00 up	3.50 up
Hotel Miami	5.50 up	3.50 up

Members and guests should indicate with whom they desire to share a room if single rooms are not available.

Chicago Site of AIEE Midwest General Meeting

During the week of November 3–7, 1947, Chicago, Ill., will be the hub of technical activity with the AIEE Midwest general meeting at the Congress Hotel, the National Electronics Conference at the Edgewater Beach Hotel, and the Second International Lighting Exposition at the Stevens Hotel. As a result of planned co-ordination, a joint session on industrial electronics will be held at the Edgewater Beach Hotel, and one on lighting at the Congress Hotel.

TECHNICAL SESSIONS

The tentative AIEE program will cover 15 technical sessions, 8 technical conferences, and 3 general meetings. Papers will be presented and discussions conducted on such subjects as power generation, transmission, distribution, communications, electronics, illumination, and new energy sources.

One of the power transmission sessions will feature a group of technical papers dealing with the Tidd 500-kv test line. One of the general sessions will be addressed by an authority on nucleonics.

INSPECTION TRIPS

On Tuesday, Wednesday, and Thursday, inspection trips are planned to visit the Fisk station of the Commonwealth Edison Company, Western Electric Company, Carnegie Illinois Steel Company, Museum of Science and Industry, Marshall Field store, Armour Research Foundation, and the electromotive division of General Motors, respectively. At all locations women and children over 16 years are invited, with the exception of the General Motors electromotive division, where proximity to heavy machinery makes it inadvisable.

WOMEN'S PROGRAM

Highlights of the women's activities will be a luncheon and bridge party plus luncheon with the men to be served during the trip to the Museum of Science and Industry. However, in addition to the scheduled events, it is expected that the women will avail themselves of the time in Chicago to visit spots like the Field Museum, Shedd Aquarium, Planetarium, and other points of interest. Many may wish to take in one or more of the plays which will be running at that time.

ADVANCE REGISTRATION

Members are asked to register in advance. This will assist the registration committee and save time on arrival. It is suggested that delegates plan to arrive on Sunday, November 2, 1947, as registration starts that afternoon. All members are requested to mention their attendance at the Midwest general meeting when writing to any Chicago hotel for reservations during that period. Hotels have been notified and will give priority accordingly.

COMMITTEES

Members of the District committee responsible for the local arrangements are F. H. Lane (F '37), *chairman;* D. L. Smith (M '27), *vice chairman;* F. V. Smith (M '38), *secretary;* and N. C. Pearcy (F '43), *treasurer.* Chairmen of the subcommittees are J. E. Hobson (M '41), hotel; A. J. Krupy (F '46), papers and meetings; L. R. Janes (M '29), inspection trips; H. K. Smith (F '44), dinner and entertainment; R. R. O'Connor (M '43), registration; R. I. Parker (M '20), publicity; P. B. Juhnke (F '36), finance; and Mrs. F. H. Lane, ladies.

Future AIEE Meetings

Middle Eastern District Meeting

Biltmore Hotel, Dayton, Ohio, September 23–25, 1947

Midwest General Meeting

Congress Hotel, Chicago, Ill., November 3–7, 1947

Winter General Meeting

William Penn Hotel, Pittsburgh, Pa., January 26–30, 1948

AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS,* and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full formal text of a technical paper including discussion, if any, as it will appear in the annual volume of *TRANSACTIONS. PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates, Members, and Fellows.

Meetings	Abstracts	PROCEEDINGS Order Forms
Winter	Jan '47, pp 84–93; Feb '47 pp 190–1	Feb '47, pp 33A and 34A
North Eastern District	Apr '47, pp 401–02	June '47, pp 55A and 56A
Summer General	June '47, pp 607–14; July '47, p 708	June '47, pp 55A and 56A

Orders Being Accepted for 1948 Transactions

Advance orders now are being accepted for volume 67 of AIEE *TRANSACTIONS* for 1948. Delivery will be made early in 1949. Because printing is started months before the completion of these annual volumes, orders received after May 1, 1948, cannot be assured of being filled.

Recent substantial rises in costs of paper

and production are reflected in a readjustment of the long established price to members, which now will be $5 instead of $4. This increase of only 25 per cent is being made despite the fact that costs have increased by 50 per cent. Subscription to nonmembers remains at $12 plus extra foreign postage; discounts from this price may be allowed to college and public reference libraries (25 per cent) and to publishers and subscription agencies (15 per cent).

Under current publication policies *TRANSACTIONS* contains all formal AIEE technical papers and related discussion as approved by the AIEE technical program committee, and other record material appropriately approved. Papers and discussion are made available to the membership as preprints from *TRANSACTIONS* through the medium of AIEE *PROCEEDINGS*, which is furnished on individual request in accordance with procedures stated from time to time in *ELECTRICAL ENGINEERING*. The substance of all papers is distributed to the entire membership through *ELECTRICAL ENGINEERING* in abstract, condensed, or full form depending on the general interest in the subject matter.

Advance orders should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y. Payment in advance is required from all except AIEE members, who will be billed individually for their orders.

New Paper Secured for Electrical Engineering

Successfully culminating a year and a half of effort in the congested and overburdened United States paper market, *ELECTRICAL ENGINEERING* introduces with this issue a better paper stock. This improvement in quality and appearance represents another step in the enlarged publication program announced last year (*EE, Dec '49, pp 576–8*) in line with previous actions by the AIEE board of directors.

New AIEE Subsection Formed at Abilene, Tex.

At a dinner meeting held in Abilene, Tex., on July 11, 1947, it was agreed unanimously to form a new Subsection to be known as the West Central Texas Division of the AIEE North Texas Section. The organization meeting was presided over by Chairman Wendell C. Fowler (M '36) of the AIEE North Texas Section.

A group of officers, including Dan W. Whitaker (M '38) *chairman*, W. D. Maddrey (M '43) *vice-chairman*, and E. N. Mitchell (A '38) *secretary*, was elected and installed at the meeting.

It is planned that this Subsection will serve members at Abilene and those in the area which includes Eastland, Ballinger, Hamlin, Big Spring, and Midland, and other nearby towns and cities.

Lamme Medal Nominations To Be Submitted by December 1

Members of the Institute again are reminded that they have an opportunity to submit nominations for the 1947 Lamme Medal. All nominations must be received not later than December 1, 1947. Details regarding qualifications have been published in *ELECTRICAL ENGINEERING* (*EE, June '47, p 596*).

The 1946 Lamme Medal was awarded to John B. MacNeill (F '42) manager of the switchgear and control division of the Westinghouse Electric Corporation, East Pittsburgh, Pa. Addresses delivered in connection with the presentation of the medal and the medalist's career appeared in last month's *ELECTRICAL ENGINEERING* (*EE, Aug '47, pp 747–53*).

STANDARDS • • •

Electric Recording Instruments (AIEE 40, July 1947). The standards in this section apply to electric recording instruments for direct or alternating current such as ammeters, voltmeters, wattmeters, volt-ampere meters, varmeters, frequency meters, power factor, reactive factor, and phase angle meters, ohmmeters and conductivity meters, and temperature recorders. They do not apply to small instruments of types and sizes that are used where low cost is essential, instruments constructed for special requirements such as instruments of very high sensitivity, or instruments whose primary function is control rather than measurement. Definition, rating, heating, determination of characteristics and influence of operating conditions, dielectric tests, insulation resistance, and construction are covered. 12 pages, 15 cents.

Aircraft Direct-Current Apparatus Voltage Ratings (AIEE 700, July 1947). Voltage rating for generators, continuous duty devices, intermittent duty devices, and battery operated devices, as well as dielectric tests and field test before use, are covered in this standard. 4 pages, 10 cents.

Report on Aircraft Electric System Guide (AIEE 750, July 1947). This draft of the report on aircraft systems guide indicates the degree of progress which has been made in the compilation of this extensive informative report. The present material is in tentative form and suggestions for improvement are welcomed. The report was prepared by the subcommittee on aircraft systems of the AIEE committee on air transportation. Purpose of requirements of the electric systems, general considerations, power equipment characteristics, control and protective equipment characteristics, system considerations, definitions, and working standards are discussed. 60 pages, no charge.

PERSONAL • • • •

G. W. Penney (A '26, F '45) manager, electrophysics department, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed George Westinghouse professor of engineering at Carnegie Institute of Technology, Pittsburgh, Pa. Professor Penney holds the degrees of bachelor of science (1923) from Iowa State College, master of science (1929) from the University of Pittsburgh. He was associated with the power engineering department of the Westinghouse Company from 1924 to 1929, at which time he was transferred to the research laboratories. He has been manager of the electrophysics department since 1936. Professor Penney has more than a dozen patents to his credit and is the inventor of the Precipitron. He is a member of Tau Beta Pi, the American Society of Heating and Ventilating Engineers, the American Physical Society, and the American Association for the Advancement of Science.

W. D. Coolidge (A '10, M '34) retired vice-president of the General Electric Company, Schenectady, N. Y., and **R. W. Sorensen** (A '07, M '19) professor and head of the department of electrical engineering, California Institute of Technology, Pasadena, are among the six scientists recently sent to Japan as expert advisers to General MacArthur's staff under the sponsorship of the National Academy of Scientists. They will evaluate plans submitted by Japanese scientific bodies for democratization of research in Japan.

D. R. Shoults (A '35, M '42) formerly vice-president of sales, Bell Aircraft Corporation, Buffalo, N. Y., has been appointed chief engineer of the Glenn L. Martin Company, Baltimore, Md. Mr. Shoults, who was graduated from the University of Idaho in 1925, was associated with the General Electric Company, Schenectady, N. Y., for almost 20 years and was engineer of the aviation division when he resigned to join Bell Aircraft Corporation in 1945. Mr. Shoults had a leading civilian role in the

D. R. Shoults

United States Government's first exploratory survey of British jet engine development and was concerned with the co-ordination of the first jet engine program in the United States. He was chairman of the AIEE air transportation committee for 1944–45 and in 1940 was awarded the AIEE national best paper prize in the field of engineering practice. He is a member of the Society of Automotive Engineers and the Institute of the Aeronautical Sciences.

B. L. Smith (M '27) formerly acting general manager, Chicago North Shore and Milwaukee Railway Company, has been appointed general manager. Mr. Smith was graduated from the University of Illinois in 1911 and has been associated with the Chicago Rapid Transit Company since that time. He has been linesman, draftsman, power supervisor, assistant electrical engineer, chief electrical engineer from 1926 to 1937, and was assistant to the executive officer when he entered active military service in 1941. After his return to the company in 1945, he was made assistant to the president. He was made acting general manager early this year. He is a past chairman of the AIEE Chicago Section. Mr. Smith is a member of the Western Society of Engineers, the American Transit Engineering Association, and the Reserve Officers Association of the United States.

A. N. Goldsmith (M '15, F '20) consulting engineer, New York, N. Y., has become an associate of Richard W. Hubbell and Associates, television consultants, in addition to his regular consulting practice. Mr. Goldsmith is a former president of the Radio Corporation of America and a past president of the Society of Motion Picture Engineers and the Institute of Radio Engineers. At present he also is editor of the *Proceedings* of the IRE.

F. E. Sanford (A '28, M '46) has resigned as Western editor of *Electrical World*, Chicago, Ill., to become director of research and development for the Copper Wire Engineering Association. Before joining *Electrical World* in 1946, Mr. Sanford was superintendent of distribution engineering for the Cincinnati (Ohio) Gas and Electric Company. He is a former chairman of the transmission and distribution committee of the Edison Electric Institute. Mr. Sanford was graduated from the University of Cincinnati in 1926.

J. C. Meier (A '44) formerly manufacturing editor, *Electrical World*, New York, N. Y., has been appointed Western editor for the magazine with headquarters in Chicago, Ill. Mr. Meier entered the Westinghouse Electric Company test course after graduation and was assistant operator when he resigned to join the editorial staff of *Electrical World* in 1944.

S. L. Rosenberg (A '46) recently electrical engineer with the United States Signal Corps, has been appointed engineer in charge of purchasing and materials control for the Estey Manufacturing Company, Inc., New York, N. Y. Mr. Rosenberg, who was graduated from the College of the City of New York in 1939, previously was associated with the Hub Engineering Company. He is a member of the Institute of Radio Engineers.

Alan Howard (A '28, M '35) and **H. D. Taylor** (A '27, M '34) formerly assistant designing engineers, General Electric Company, Schenectady, N. Y., have been appointed section engineers of the gas turbine section and of the generator section, respectively. Mr. Howard has been with the company since 1927, the year he was graduated from Purdue University. Mr. Taylor, a graduate of the University of Wisconsin, entered the General Electric student's course in 1921.

H. W. Tenney (M '36, F '43) formerly assistant to the vice-president, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed operating manager of the company's elevator division in Jersey City, N. J. Mr. Tenney joined the Westinghouse Company as a laboratory assistant in the research department in 1920, the year he was graduated from Worcester Polytechnic Institute. He has held the positions of division engineer of materials and processing, manager of the central engineering laboratories, engineering manager of the products division, and assistant director of the research laboratories. He was made assistant to the vice-president in 1943.

P. M. Gentzel (M '39) superintendent of distribution, Ohio Public Service Company, Elyria, has been appointed to the newly created commission of co-ordinator of employees relations for the company. Mr. Gentzel will adjust all differences between employees and supervisors and will be in charge of the training school for junior engineers and the company's safety program. He has been with the company since 1920.

A. B. Cooper (M '16, F '33) chairman of the board, Ferranti Electric Ltd., Toronto, Ontario, Canada, has been appointed to the board of Ferranti Ltd., of England. Mr. Cooper is a past vice-president of AIEE.

D. T. Siegel (M '45) president, Ohmite Manufacturing Company, Chicago, Ill., has been appointed chairman of the wire wound resistance section of the Radio Manufacturers Association.

C. W. Miller (A '30, M '37) manager, radio application department, Westinghouse Electric Corporation, Baltimore, Md., has been appointed 1947–48 chairman of the broadcast transmitter section of the transmitter division of the Radio Manufacturers Association.

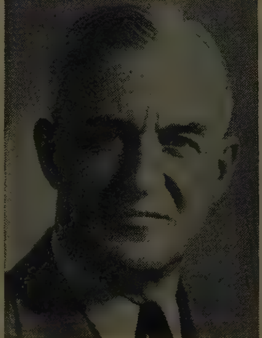
J. L. Highsmith (A '42) formerly field engineer, sales department, Leeds and Northrup Company, Philadelphia, Pa., has been appointed sales representative for C. T. Clare and Company, Chicago relay manufacturers, in North Carolina and South Carolina. His headquarters will be at Durham, N. C.

A. M. Perry (A '32, M '42) formerly deputy electrical engineer and manager, Southwark (England) Corporation, has been appointed to that position for the Grimsey (England) Corporation.

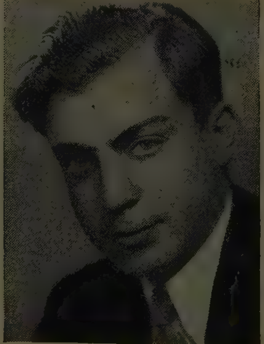
W. S. Beck (A '44) has been appointed assistant manager of the industries department, Westinghouse Electric International Company, New York, N. Y. A 1928 graduate of the University of Pennsylvania, Mr. Beck joined the industry department of the Westinghouse Company in 1936.

Onni Lindfors (A '33) of the electrical department, Fairbanks, Morse and Company, Beloit, Wis., has been appointed chief electrical engineer of the company's Freeport, Ill., plant.

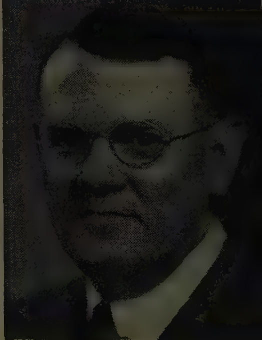
D. A. Griffith (A '39) formerly application engineer, electric department, Allis-Chalmers Manufacturing Company, Pittsburgh, Pa., has been appointed assistant to the general manager of the company's Pitts-



A. B. Cooper



S. L. Rosenberg



H. W. Tenney

D. A. Quarles

H. D. Beebe

R. M. Mock

burgh works. A graduate of Carnegie Institute of Technology, he has been associated with the company since 1927.

D. A. Quarles (A '23, F '41) director of apparatus development, Bell Telephone Laboratories, Inc., New York, N. Y., has been elected a vice-president of the company. Mr. Quarles has been associated with the Bell System since 1919 and previously has served as outside plant development director and transmission development director. He is vice-chairman of the Committee on Electronics of the Joint Research and Development Board of the Federal Government. At present he also is serving as a director of the AIEE.

R. M. Mock (A '44) vice-president in charge of the electromechanical division, Lear, Inc., has been appointed executive vice-president of the company. Mr. Mock, who was graduated from New York University in 1925, has been with the Lear Corporation since 1933. His extensive experience in the aircraft industry has included associations with Bellanca Aircraft Corporation, Newcastle, Del.; the Heinkel Works in Germany; the Fokker Aircraft Company of America; and the Douglas Aircraft Company.

H. D. Beebe (M '44) formerly transmission superintendent, Tampa Electric Company, has been appointed general superintendent. Mr. Beebe joined the company in 1935 after his graduation from Yale University.

F. J. Rudd (M '19) managing engineer, motor division, General Electric Company, Lynn, Mass., has retired. Mr. Rudd, a graduate of Virginia Polytechnic Institute, joined the company as a student engineer in 1901. Transferred to the motor division the following year, he was made assistant on design work and in 1929 was appointed designing engineer. He has been managing engineer since 1932.

H. A. Triplett (A '18, M '21) formerly chief engineer, S & C Electric Company, Chicago, Ill., has become engineer in charge of power switching equipment for the A. B. Chance Company, Centralia, Mo. **B. O. Watkins** (A '43, M '46) formerly senior engineer, Rural Electrification Administration, Washington, D. C., also has joined the Chance Company. Mr. Watkins will be construction and maintenance equipment engineer. Mr. Triplett joined the S & C Company in 1925 as electrical engineer and was appointed chief engineer in 1937. He holds more than 40 patents. Mr. Watkins became a member of the technical standards division of REA in 1937 and later worked on Administration projects in Michigan and Arizona. During the war he served in the Pacific area.

R. J. Standerwick (A '21) designing engineer, General Electric Company, Lynn, Mass., has retired. Born and educated in England, he commenced his engineering career in the United States with the General Electric Company in 1909. He has been associated with arc lamp, steam turbine, and air-conditioning development. In 1933 he was appointed chief designing engineer of the mechanical drive turbine division and in 1941 was appointed engineer of the supercharger engineering division.

W. C. Kochendoerffer (M '38) division engineer, electrical engineering department, Consolidated Edison Company of New York (N. Y.) Inc., has retired. Mr. Kochendoerffer was associated with the New York Public Service Commission from 1906 to 1916 during the planning and construction of the rapid transit subway. After wartime service with the Corps of Engineers, he joined Edison in 1922.

A. J. Girdwood (A '40) formerly assistant engineer, a-c engineering department, Canadian General Electric Company, Ltd., Peterboro, Ontario, Canada, has been appointed chief engineer of Leland Electric Canada, Ltd. Mr. Girdwood has been with the Canadian General Electric Company since his graduation from the University of Toronto in 1934. He is a member of the Professional Engineers of Ontario, the Institution of Electrical Engineers, and the Engineering Institute of Canada.

L. M. Robertson (A '27, F '45) transmission and station engineer, Public Service Company of Colorado, Denver, has been elected vice-president of the Colorado Engineering Council.

G. G. Rae (A '41) recently returned from naval duty, has been appointed manager of the Controlens division of the Holophane Company, Inc., New York, N. Y. Mr. Rae was graduated from the Polytechnic Institute of Brooklyn in 1937 and before the war was field engineer for the company in Washington, D. C.

E. B. Kipp (A '35, M '42) formerly engineer, electric meter department, San Diego (Calif.) Gas and Electric Company, has been appointed superintendent of the electric meter division. A 1926 graduate of the University of Utah, Mr. Kipp recently was associated with the Westinghouse Electric Manufacturing Company.

T. H. Hogg (M '31, F '38) retired chairman, Hydro-electric Power Commission of Ontario, Toronto, Canada, and **R. L. Hearn** (M '23) present chairman of the Commission, Canada, recently were presented with ornamental gifts from India in recognition of the contributions they have made toward the training of Indian electrical engineers.

A. H. Sammis (A '20, M '38) president, Ohio Edison Company, Akron, has been nominated to the board of trustees of Columbia University, New York, N. Y., as alumni representative.

C. L. Peirce, Jr. (A '25) president, Hubbard and Company, Pittsburgh, Pa., has been elected chairman of the board of that company. Mr. Peirce became associated with the Hubbard Company in 1909 when the latter purchased the Peirce Specialty Company. He was elected vice-president in 1926 and president in 1929.

B. A. Case (A '30, M '44) assistant design engineer of the fractional-horsepower motor engineering division, General Electric Company, Fort Wayne, Ind., has been appointed a member of the design engineering staff of the company's apparatus department.

R. W. Klinck (A '33) engineer with the American Can Company, Vancouver, British Columbia, Canada, has been appointed head of the engineering division of the British Columbia Research Council.

A. J. Sutton (A '43) engineer with the British Columbia Electric Railway Company, Ltd., Vancouver, Canada, has been elected president of the company's office employees association.

L. T. Rader (A '34, M '43) formerly director, electrical engineering department, Illinois Institute of Technology, Chicago, has returned to the General Electric Company.

OBITUARY • • • •

Norman Wilson Storer (A '95, F '13) retired consulting railway engineer, Westinghouse Electric Corporation, died June 5, 1947. He was born at Orangeville, Ohio, January 11, 1868, and graduated from Ohio State University with the degree of mechanical engineer in electrical engineering in 1891. In September of that year he entered the employ of the Westinghouse Company at East Pittsburgh, Pa., in which he continued without interruption until his retirement in 1936. In 1893, he became assistant to B. G. Lamme on the design of d-c machines, especially railway motors. During this period he developed a method of rating railway motors which later was adopted as standard by both the AIEE Standards committee and the International Electrotechnical Commission. In 1904 the company's engineering department was reorganized, and Mr. Storer was made engineer of the railway division, devoting his entire time to electric transportation. He made notable contributions to the development of both single-phase and high-voltage d-c railway electrifications, and later had charge of developing electric equipment for oil electric cars and locomotives. In 1926 he was appointed consulting railway engineer. He was awarded the AIEE Lamme Medal for 1939 "for meritorious achievement in the development of apparatus and machinery for electrical transportation." He served the Institute as manager (1911–13) and twice as vice-president (1914–16, 1921–23); he also was Institute representative on the United States National Committee of the International Electrotechnical Commission, for which he was adviser on railway motors, and was active on technical committees, especially the Standards and transportation committees. He is the author of many technical papers. In 1933 he was awarded the Lamme Medal of Ohio State University.

Walter Lewis Smith (A '23) chief safety engineer, Department of Water and Power, City of Los Angeles, Calif., died June 28, 1947. Born June 21, 1885, Mr. Smith was graduated from the University of Cincinnati in 1912. He joined the Department's bureau of power and light in 1916 and in 1922 was appointed to head the communications and accident prevention section. He had been chief safety engineer since 1931. Mr. Smith was active in the National Safety Council.

Alden C. Cummins (A '11) general superintendent, Carnegie-Illinois Steel Corporation, Youngstown, Ohio, died July 10, 1947. Mr. Cummins, who was born in 1887, was graduated from Lehigh University in 1910. Mr. Cummins commenced his association with Carnegie-Illinois Corporation in 1911, at which time he was employed as an electrical draftsman at the Duquesne, Pa., works of the corporation. He was named superintendent of the electrical department in 1919, and assistant general superintendent of the plant in 1932. Transferred to Pittsburgh, Pa., in 1936, he was appointed assistant manager of operations in that district. He became general superintendent at Youngstown in 1940. A life member of the Association of Iron and Steel Engineers, Mr. Cummins served as president of that association in 1925 and was an honorary director for several years.

Joseph Brodie Smith (A '94, M '26) vice-president, Public Service Company of New Hampshire, Manchester, died recently. Mr. Smith, who was born April 6, 1851, in Richville, N. Y., was descended from a member of Plymouth Colony. He established an electrical contracting business in Manchester in 1885, when he also became superintendent of the city's fire alarm telegraph. A year later he became superintendent of the Benjamin Franklin Electric Light Company, which shortly afterwards combined with the Manchester Electric Light Company. He was elected director in 1894 and general manager in 1896, continuing in that position when the Manchester Traction Light and Power Company absorbed the earlier company. He was appointed vice-president in 1905 and remained in that position with the Public Service Company. Mr. Smith was active in local civic, charitable, and business affairs.

Theodore Doane Crocker (M '44) president, Northern State Power Company, Minneapolis, Minn., died June 29, 1947. Mr. Crocker was born October 18, 1878, in Elyria, Ohio, and was graduated from Ohio State University in 1904. His early experience was gained at the Milwaukee Electric Railway and Light Company and the Lincoln Electric Company, Cleveland, Ohio. He joined the Northern States Company in 1912 as commercial engineer, shortly afterwards becoming assistant to the vice-president and general manager. He was made assistant general manager in 1923, vice-president and director in 1931, vice-president and general manager in 1942, and president and director in 1943. Mr. Crocker was one of the principal organizers of the North Central division of the National Electric Light Association and served several terms as president.

Theodore Siu Huang, (M '37) chief engineer, Tungsten Products Corporation, North Bergen, N. J., died recently. Born in China in 1897, Mr. Huang was graduated from Cornell University in 1920 with the degree of master of mechanical engineering. He was design engineer for the New York (N. Y.) Edison Company until 1922, in which year he joined the Stone and Webster Engineering Corporation as an electrical engineer. At one time he was associated with the Hygrade Sylvania Corporation's Emporium, Pa., plant.

Charles Frederick Meyerherm (A '14, M '21) president and engineer, Albert F. Ganz, Inc., New York, N. Y., died July 27, 1947. Mr. Meyerherm was born February 4, 1889, in Brooklyn, N. Y., and was graduated from Stevens Institute of Technology in 1911 with the degree of mechanical engineering. He joined the Ganz Company in 1915 and became president in 1925. Mr. Meyerherm was a member of the National Society of Professional Engineers, the New York State Society of Professional Engineers, the New York Electrical Society, and the American Water Works Association. He was the author of numerous technical articles.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting of July 17, 1947, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Cotter, W. F., chief engr., Scott Radio Labs., Inc., Chicago, Ill.
Lowe, H. L., chief elec. engr., Ebasco Services, Inc., New York, N. Y.
Martin, E. R., chief elec. engr., Standard Dayton Corp., Dayton, Ohio.
McHenry, M. J., director, promotion & load dev., The Hydro-Electric Pr. Comm. of Ontario, Canada.
Mirick, C. B., elec. engr., U. S. Naval Research Lab., Washington, D. C.
O'Brien, B., research prof. physics & optics; director, Institute of Optics, University of Rochester, N. Y.
Oldacre, M. S., director of research, Utilities Research Comm., Commonwealth Edison Co., Chicago, Ill.
Peterson, H. A., prof. elec. engg., Univ. of Wisconsin, Madison, Wis.
Pierce, R. E., elec. engr., Ebasco Services, Inc., New York, N. Y.
Thompson, H. H., engg. & service mgr., Westinghouse Elec. Corp., Washington, D. C.
VanNess, B., Jr., chief engr., Safe Harbor Water Pr. Corp., Baltimore, Md.

11 to grade of Fellow

To Grade of Member

Allen, C. A., elec. designer, United Engineers & Constructors, Philadelphia, Pa.
Baird, M. N., designing engr., General Elec. Co., Fort Wayne, Ind.
Bankson, H. D., electronics engr., P-4, War Dept., Army Security Agency, Washington, D. C.
Bauman, C. E., chief elec. engr., Harza Engg. Co., Chicago, Ill.
Bertolet, W. B., industrial power engr., Metropolitan Edison Co., Easton, Pa.
Bossert, H. F., elec. engr., Office Chief Signal Officer, U. S. Army, Washington, D. C.
Boulson, C. E., chief engr., Sho-Me Pr. Cooperative, Marshfield, Mo.
Bowen, G. W., engr., Commonwealth Edison Co., Chicago, Ill.
Brock, A. E., mgr., circuit breaker div., Pacific Elec. Mfgr. Corp., San Francisco, Calif.
Brown, C. B., research physicist, Naval Gun Factory, Washington, D. C.
Camras, M., research physicist, Armour Research Foundation, Chicago, Ill.
Capodanno, R. T., section engr., Philco Corp., Philadelphia, Pa.
Cecchetti, F., engr., Dept. of Agriculture, Rural Electrification Adm., Washington, D. C.
Cobean, R. W., design engr., General Elec. Co., Schenectady, N. Y.
Cox, A. A., engr., turbine & rectifier dept., Australian General Elec. Ltd., Sydney, Australia.
Dodrill, G. E., engr., Dept. of Agriculture, Rural Electrification Adm., Washington, D. C.
Evans, B., elec. engr., P-4, U. S. Bureau of Reclamation, Denver, Colo.
Gieser, L. B., engr., Potomac Elec. Pr. Co., Washington, D. C.
Gross, C. M., senior engr., Commonwealth Edison Co., Chicago, Ill.
Hannum, W. T., div. supt., Pacific Gas & Elec. Co., Chico, Calif.

Harc, S. V., dev. engr., Victor Div. of Radio Corp. of America, Camden, N. J.
Hartranft, A. C., asst. chief load dispatcher, Phila. Elec. Co., Philadelphia, Pa.
Hendrix, H. B., materials engr., Tennessee Valley Authority, Knoxville, Tenn.
Hoopes, D. R., supv., engg. & serv. div., Westinghouse Elec. Corp , Salt Lake City, Utah.
Hopkins, H. A., engr., Davenport Works, General Elec. Co., Toronto, Ont., Canada.
Hughes, D. A., elec. engr., factory planning dept., Western Elec. Co., Kearny, N. J.
Ikerd, H. M., radio engr., Naval Research Lab., Bellevue, Washington, D. C.
Johnson, W. R., asst. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Kenney, H. M., motor specialist, N. Y. dist., General Elec. Co., New York, N. Y.
Killen, R. B., system planning engr., Dayton Pr. & Lt. Co., Dayton, Ohio.
Kranenburg, P. J., elec. engr., Ebasco Services, New York, N. Y.
Kunde, C. O., elec. engr., Navy Dept., Bureau of Ships, Washington, D. C.
Loomis, R. O., special engr., Georgia Pr. Co., Atlanta, Ga.
Lynn, L. B., advisory engr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Marvin, J. R., senior ordnance engr., Bureau of Ordnance, U. S. Navy Dept., Washington, D. C.
Marvin, P. R., director of research & dev., Milwaukee Gas Specialty Co., Milwaukee, Wis.
Maslin, A. J., advisory engr., Westinghouse Elec. Corp., Sharon, Pa.
Mason, H. J., power transformer design engr., General Elec. Co., Pittsfield, Mass.
Masters, D. B., assoc. engr., Consumers Pr. Co., Jackson, Mich.
Matthews, R. B., elec. engr., Milwaukee Gas Specialty Co., Milwaukee, Wis.
McEver, R. W., substation & underground engr., Knoxville Utilities Bd., Knoxville, Tenn.
McNicol, J. E., technical engr., Kansas Gas & Elec. Co., Wichita, Kans.
Messmer, G. R., engr., Dept. of Agriculture, Rural Electrification Adm., Washington, D. C.
Michalowicz, J. C., instructor, elec. engg., The Catholic Univ. of America, Washington, D. C.
Miller, R. D., chief elec. engr., San Francisco Naval Shipyard, Calif.
Millman, J., asst. prof. elec. engg., The City College of New York, N. Y.
Munson, L. J., elec. engr., III, communication sec., Tennessee Valley Authority, Chattanooga, Tenn.
Nims, P. T., elec. engr., research staff, Chrysler Corp., Detroit, Mich.
O'Halloran, T. A., genl. engr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Palmer, W., project engr., Sperry Gyroscope Co., Great Neck, N. Y.
Parker, G. R., chief engr., Elec. Power Bd., Chattanooga, Tenn.
Peddicord, H. R., genl. engr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Perine, W., supv. technical services, technical supv. for associate contracts, Johns Hopkins Univ., Silver Springs, Md.
Platz, E. T., research engr., Bull Dog Elec. Products Co., Detroit, Mich.
Ratliff, A. H., elec. engr., Oklahoma Gas & Elec. Co., Shawnee, Okla.
Rixse, J. H., Jr., engr., Dept. of Agriculture, Rural Electrification Adm., Washington, D. C
Robertson, L. T., div. trans. engr., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Romnes, H. I., radio engr., American Tel. & Tel. Co., New York, N. Y.
Rothpletz, M. W., engr., Dept. of Agriculture, Rural Electrification Adm., Washington, D. C.
Russ, R. B., electronic tube design engr., General Elec. Co., Schenectady, N. Y.
Sangster, H. L., engr., Potomac Elec. Pr. Co., Washington, D. C.
Schlotterback, E. M., senior engr., Central Ill. Lt. Co., Peoria, Ill.
Schwarz, S. J., elec. engr., Corbett, Tinghir & Co., New York, N. Y.
Signor, C. B., engr., N. Y. State Elec. & Gas Corp., Binghamton, N. Y.
Slingluff, B. F., elec. engr., Potomac Elec. Pr. Co., Washington, D. C.
Sloan, K. H., senior elec. engr., office of supv. of shipbldg., U. S. Navy, New York, N. Y.
Smith, O. J. M., chief elec. engr., research & dev. labs., Summit Corp., Scranton, Pa.
Sprowl, S. M., Jr., meter engr., Duke Power Co., Greensboro, N. C.
Taylor, O. R., div. costs engr., American Tel. & Tel. Co., Chicago, Ill.
Toomey, J. F., elec. engr., Naval Gun Factory, Washington, D. C.
Weiser, C. H., plant personnel supv., Southwestern Bell Tel. Co., Kansas City, Mo.
White, H. A., district mgr., apparatus dept., General Elec. Co., Dallas, Tex.
Williams, H. S., elec. engr., Dept. of Agriculture, Rural Electrification Adm., Washington, D. C.
Wurster, J. H., engr., General Elec. Co., Pittsfield, Mass.
Zambell, H. G., dev. engr., Allis-Chalmers Mfgr. Co., Pittsburgh, Pa.

75 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before September 21, 1947, or November 21, 1947, if the applicant resides outside of the United States or Canada.

To Grade of Member

Angelini, A. M., Terni Co., Terni, Italy.
Armi, E. L., Mica Insulator Co., Schenectady, N. Y.
Benner, P. E., General Elec. Co., Schenectady, N. Y.
Burgess, B. I., Canadian General Elec. Co., Peterboro, Ontario, Canada.
Campbell, P., West Texas Utilities Co., Abilene, Tex.
Chandler, W. H., NDHQ, Ottawa, Ontario, Canada.
Coleman, J. H., E. I. du Pont de Nemours & Co., Wilmington, Del.
Cramer, H. A., Glenn L. Martin Co., Baltimore, Md.
Decker, R. H., 188 W. Randolph St., Chicago, Ill.
Duncan, J. W., 120 Boylston St., Boston, Mass.
Eggers, E. B., Ill. Inst. of Tech., Chicago, Ill.
Fitzgibbon, James J., General Elec. Co., Charleston, W. Va.
Gale, H. M., Messrs. Elliott Bros. (London), Ltd., Borehamwood, Hertfordshire, England.
Harris, H. R., Detroit, Edison Co., Detroit, Mich.
Hendrickson, D., East Bay Municipal Utility District, Oakland, Calif.
Hosticka, F. J., Visking Corp., Chicago, Ill.
Huguelet, J. E., Albert Kahn, Inc., Detroit, Mich.
Johns, L., The Victoria Falls & Transvaal Power Co., Ltd., Brakpan, South Africa.
Johnson, C. N., (re-election), Burke Elec. Co., New York, N. Y.
Landau, M., Dept. of Water & Pr., Los Angeles, Calif.
Lantz, G. J., Volt Elec. Co., Orlando, Fla.
Latour, A., Ets. Merlin & Gerin, Grenoble, France.
Merlin, P., Ets. Merlin & Gerin, Grenoble, France.
Mustafa, S., Godavari Valley Authority, Hyderabad, Deccan, India.
Pike, A. L., A. R. Williams Machinery Western, Ltd., Vancouver, British Columbia, Canada.
Rhoades, H. E., Northern States Pr. Co., Minneapolis, Minn.
Rice, J. E., Jr., Western Union Tel. Co., New York, N. Y.
Schaer, F., Aare-Tessin A. G. für Elektrizitat, Olten, Switzerland.
Sorensen, S. V. T., AEG Companhia Sul-Americana de Electricidade, São Paulo, Brazil, S. A.
Tindall, H. D., Moloney Elec. Co., St. Louis, Mo.
Tucker, S. A., Tucker & Co., New York, N. Y.

31 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Anderson, E. R., General Elec. Co., West Lynn, Mass.
Bejach, B. O., General Elec. Co., West Lynn, Mass.
Hatfield, E. J., Jr., General Elec. Co., Schenectady, N. Y.
Hummer, J. L., Rhode Island State Coll., Kingston, R. I.
Kool, S. E., Stone & Webster Engg. Corp., Boston, Mass.
Lasher, H. S., Jr., General Elec. Co., Schenectady, N. Y.
Liss, S., General Elec. Co., Bridgeport, Conn.
Nowak, E. F., Federal Elec. Prod. Co., Hartford, Conn.
Tanner, J. A., General Elec. Co., Pittsfield, Mass.

2. Middle Eastern

Aldrich, S. J., Air Matériel Command, Wright Field, Dayton, Ohio.
Barnes, H. W., R. E. Uptegraff Mfg. Co., Scottdale, Pa.
Beatty, C. G., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Bridenbaugh, R. W., Frigidaire Co., Moraive City, Ohio.
Cowan, C. R., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Helpern, W. J., Kyle Corp., Columbus, Ohio.
Hennie, R., Jr., Republic Steel Corp., Cleveland, Ohio.
Holwick, R. L., Buckeye Steel Castings Co., Columbus, Ohio.
Johansson, A. V., General Elec. Co., Erie, Pa.
Mahoney, M. G., The Dingle-Clark Co., Cleveland, Ohio.
Meunier, F. A., Republic Steel Corp., Cleveland, Ohio.
Phillips, E. V., Naval Research Lab., Washington, D. C.
Sarria, J. J., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Schoenberg, M. L., Philco Corp., Philadelphia, Pa.
Tremaine, R. L., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Veerman, G., Intl. Corres. Schools, Scranton, Pa.

3. New York City

Blount, R. H., USN, USS *Rochester*, FPO, New York, N. Y.
Johnson, E. M., Mutual Broadcasting System, Inc., New York, N. Y.
Lidsky, H. A., L. & P. Elec. Construction Corp., Brooklyn, N. Y.
Robinson, G. L., Pitometer Log Corp., New York, N. Y.

4. Southern

Abbitt, W. H., Virginia Elec. & Pr. Co., Norfolk, Va.
Farrar, E. M., Elec. Dept., Culpeper, Va.
Harp, W. I., Southern Bell Tel. & Tel. Co., Jackson, Miss.

5. Great Lakes

Meese, W. G., Detroit Edison Co., Detroit, Mich.
Sargent, H. C., Superior Water, Lt. & Pr. Co. Superior, Wis.
Sloan, C. D., (re-election), The Indiana Steel Products Co., Valparaiso, Ind.

6. North Central

Bretey, W. J., U. S. Bureau of Reclamation, Seminoe Dam, Wyo.
Clark, W. L., U. S. Bureau of Reclamation, Seminoe Dam, Wyo.

7. South West

Cratin, P. F., War Dept., Corps of Engrs., Little Rock, Ark.
Davis, C. M., Elgin B. Robertson, Inc., Houston, Tex.
Dorroh, G. B., Dow Chemical Co., Freeport, Tex.
Hammann, J. W., Missouri School of Mines, Rolla, Mo.
Hughes, F. A., Jr., El Paso Elec. Co., El Paso, Tex.
Jester, M. D., Central Pr. & Lt. Co., Corpus Christi, Tex.
Lambert, R. J., White Rodgers Elec. Co., St. Louis, Mo.
Lea, L. L., A & M Coll. of Texas, College Station, Tex.
Salmon, F. A., Central Pr. & Lt. Co., Corpus Christi, Tex.

8. Pacific

Althouse, C. F., U. S. Navy Electronics Lab., San Diego, Calif.
Anderson, A. T., North American Aviation, Inc., Los Angeles, Calif.
Binns, B., General Elec. Co., San Francisco, Calif.
Kappenman, E. A., Jr., Sacramento Municipal Utility Dist., Sacramento, Calif.
Lorens, W. F., Lt. Comdr., USN, USS *Eversole* (DD789), FPO, San Francisco, Cal f.
Mumaw, J. P., Southern Calif. Edison Co., Los Angeles, Calif.
Smith, D. J., Pacific Tel. & Tel. Co., San Francisco, Calif.
Thompson, A. C., Bureau of Reclamation, Boulder City, Nev.

9. North West

10. Canada

Cardell, T. E., Calgary Pr. Co., Ltd., Calgary, Alberta, Canada.
Nayar, V. G. G., c/o M/s Aluminum Industries, Ltd., Montreal, Quebec, Canada.
Taylor, W. O., (re-election), W. O. Taylor & Co., Ltd., Montreal, Quebec, Canada.
Tuttle, P. D., Quebec Hydro-Elec. Comm., Montreal, Quebec, Canada.

Elsewhere

Bansal, S. K., Marconi Coll. of Wireless Communication, Chelmsford, England.
Bulford, F. F., Johnson & Phillips, Ltd., Charlton, London, England.
Chapiro, J., S.I.A.M. Di Tella Ltd., Buenos Aires, Argentina, S. A.
Datta, H. L., The Rawalpindi Elec. Pr. Co., Ltd., Rawalpindi, Punjāb, India.
Jacobs, G. B., Anchorage Municipal Pr. Co., Anchorage, Alaska.
Lengnick, L. W., The Hawaiian Elec. Co., Honolulu, T. H.
Low, C. H., Tientsin Pr. Co., Tientsin, China.
Mani, C. V., Auto Elec. & Radio Service Co., Secunderabad, Deccan, India.
Webb, P. R. W., Royal Engineers Squadron, British Army, London, England.

Total to grade of Associate

United States, Canada, and Mexico, 58
Elsewhere, 9

OF CURRENT INTEREST

138,000-Volt Cable Systems Installed in New York

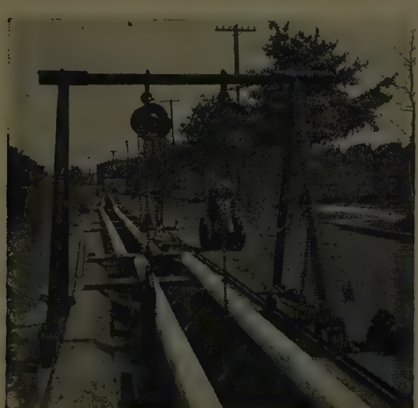
On July 31, 1947, the first length of 138-kv compression-type pipe cable was installed in the current Consolidated Edison Company of New York (N. Y.) Inc.'s extensive tie expansion program. The compression-type cable installation is the first commercial installation of its kind to be made in the United States. The tie program includes two 138-kv feeders between the Hudson Avenue generating station and a new distributing station at Jamaica, N. Y., and one 138-kv feeder between Jamaica and the Valley Stream, N. Y., substation of the Long Island Lighting Company.

The Hudson Avenue–Jamaica lines will consist of three single-conductor 1.5-million-circular-mil paper-insulated cables per $8^5/_8$-inch outside diameter steel pipe. These lines will be operated as conventional high-pressure oil-type cables, surrounded by oil at 200 pounds pressure in direct contact with the insulation.

The Jamaica–Valley Stream line will consist of three single-conductor 350-thousand-circular-mil paper-insulated cables installed in a 6-inch outside diameter steel pipe. These cables are of the compression type of oval shape and have an extruded polyethylene jacket. The polyethylene jacket is not removed in the field but remains on the cable after installation in the pipe. The cables will be surrounded by oil at 200 pounds pressure.

The installation of the 6-inch steel pipe was begun on May 16, 1947. Two pipes were installed in a common trench, each pipe approximately 30,000 feet in length in the Edison section, one pipe for the present feeder and the second for a future installation if required. The installation of the two $8^5/_8$-inch steel pipes in a common trench was begun on July 11, 1947. Each pipe will be approximately 40,000 feet in length.

The pipes are installed in city streets and the illustration shows the pipe in place for welding of individual lengths.



Pipe supported over trench on padded timbers for welding of individual lengths

RCA Develops New Television Camera

A studio-type image orthicon television camera, requiring only one-tenth the amount of light needed with present-day iconoscope cameras, has been developed by the RCA engineering products department of the Radio Corporation of America. The new unit produces pictures with excellent half-tone shading and with lower noise level than the field-type image orthicon. It eliminates the need for expensive and uncomfortable studio lighting, and the attendant oversize air conditioning plants and eye straining glare, by producing sharply defined pictures at light levels of 100–200 foot-candles. It will function at light levels down to 25 foot-candles.

Heart of the new camera is a new studio-type image orthicon pickup tube which combines the light sensitivity of the original image orthicon tube with the sharp resolution and contrast of the iconoscope. A feature of the new tube is the elimination of the spurious "black spot" signals which occur in conventional camera tubes and require constant manual adjustment for their control. Slightly larger than the portable image orthicon television field camera, the new studio camera is designed for use on a dolly or pedestal. It has a battery of four lenses mounted in a rotary turret, the necessary circuits for deflecting the scanning beam, and a video amplifier to increase the amplitude of the signals obtained from the pickup tube.

The new camera also has a self-locking screw focusing mechanism and a built-in electronic view finder and hood. Optical focusing of the studio camera is accomplished by rotating a large knob on the right side of the camera, which moves the pickup tube backward or forward, together with its focus and deflection coil assembly. In this way the scene is brought into focus on the photoelectric cathode of the tube without having to move the lenses. A wide range of adjustments is possible with the combination of this focusing mechanism and the focusing mounts of the Ektar lenses which are mounted in the turret. The lenses used in the turret are of the Ektar type, and are available in sizes from 35 millimeters at f 2.8 to 135 millimeters at f 3.8, adequately covering all studio requirements. The depth of focus is such that refocusing seldom is required.

The operator focuses the picture in the camera by observing the image on the screen of the electronic viewfinder. This viewfinder employs a 5-inch kinescope which permits the operator to see the exact image that his camera is picking up. Since this picture is identical to that which is being transmitted to the camera control equipment, the operator only has to frame accurately and focus the picture, and at the same time he is able to monitor its quality. The electronic viewfinder eliminates the need for a complete set of duplicate lenses, which would be required for an optical view-finding system.

First Annual Store Modernization Show Held

The first annual store modernization show was held at the Grand Central Palace, New York, N. Y., July 7–12, 1947. The main theme of the show was store modernization through improved lighting. A number of manufacturers prominent in lighting fixtures and lighting equipment featured their products at various exhibits, and a number of clinic discussions on various phases of lighting such as store lighting, modernized materials, and modernized display of fixturing, were held for the benefit of interested visitors. A discussion of lighting fixtures and lighting equipment also was held.

German Secrets Being Sold by Federal Agency

The Office of Technical Services, which has been collecting, classifying, and microfilming German patents and technological documents since the end of the war, reports that more than 400,000 copies of scientific documents have been sold to American concerns at an average fee of \$3 to \$4 per document. New orders are coming in from American businessmen at the rate of about 1,000 a day.

Many of the processes and inventions are considered priceless by officials. Several large United States corporations are said to have been willing to pay as high as \$20,000,000 for exclusive rights to a German process. The Government, however, has laid down the policy that seized scientific information is to be made available to all comers at nominal fees. Some 75,000 original technological reports have been processed so far and there are still about 400,000 documents yet to be done.

It is estimated that the Russian government has purchased \$17,000 worth of documents totaling nearly 5,000 separate items. The Russian purchasing agency, Amtorg, has been ordering documents at a token price since last year, according to officials. Although Commerce Department officials at first were reluctant to sell

the information to the Russian government, the State Department laid down the policy that reports should be sold to Amtorg because the material is being made public and anyone could write in and get it. To date the sale of these documents has yielded the Commerce Department a gross revenue of $1,500,000.

GE Project Explains Oil Field Electrification

A program designed to help meet the growing demand for oil by explaining the opportunities and over-all benefits of electric power in the production and pipe-line transportation of oil has been launched by the General Electric Company, Schenectady, N. Y. The oil field electrification program is designed for use by electrical utilities, machinery and equipment manufacturers, electrical contractors, drilling contractors, distributors and supply houses, consulting engineers, government agencies interested in oil production, and petroleum associations.

Much of the program is educational, featuring sound motion pictures in color, pamphlets and books outlining the advantages of electrification, and informal discussions with audiences which include oil field and pipe-line operators, petroleum associations, technical societies, engineering colleges, vocational schools, and service clubs. It is made available at cost to co-operating groups in the form of a kit containing a 16-millimeter motion picture, three copies of an application textbook, and 25 copies of a publication for distribution to audiences seeing the film.

The new oil field electrification project is the latest release in General Electric's "More Power to America Program" which provides information and material for co-operative promotion by interested groups of more efficient use of electric power and increased productivity.

Airport Lighting System for All-Weather Approach

An airport approach lighting system designed to penetrate 1,000 feet of the thickest fog has been announced by the Westinghouse Electric Corporation. The system includes three component parts: approach lights, runway designator, and runway lights.

Thirty-six krypton flash units are placed in line alternately with 36 neon blaze units for a distance of almost three quarters of a mile from the approach portal to the start of the runway. The krypton lamps are only four inches long but, when a surge of electricity heats the gas to incandescence, the lamp flashes with a maximum brightness of 9,000,000 candlepower per square inch. The reflector and optical system of the lighting fixtures magnifies this flash to 3.3 billion candlepower. When flashed rapidly one after another, the line of lamps appears like a stroke of lightning traveling toward the airport landing strip. Flashing 40 times a minute, this line of light can be seen for at least 1,000 feet even in zero-zero visibility. In clearer weather, intensity of the approach lights is reduced and the krypton units can be turned off in favor of the less brilliant neon blaze units that can be used as either flashing or steady burning lamps. Brilliance of the neon units can be reduced to as little as 100 candlepower on clear nights.

An 83-foot combination red cross or green arrow serves to direct runway traffic. As the pilot approaches the beginning of the runway, he sees on the ground a brilliant green arrow 83 feet long, indicating that the runway is all clear for his landing. This is called the runway designator. If for some reason the runway is not clear, the designator is changed to a flashing red cross. The arrow and cross are formed by green zeon or red neon tubular lamps.

New high-intensity runway lights, each casting a beam of 100,000 candlepower intensity, give the pilot an accurate picture of the runway's width and direction. Although 100,000 candlepower can be used under the worst visibility conditions, brightness can be reduced gradually to five candlepower for clear night operation.

To help make foggy weather landings routine for pilots, two approach angle indicators are installed near the head of the runway. These tell pilots in clear weather that they are coming in at exactly the right altitude for a perfect landing. Projecting a tricolor beam, sharply divided into horizontal layers, these indicators appear as flashing yellow lights if the airplane is too high, red if it is too low, and green when the rate of descent is correct. The system requires no additional equipment on the airplane. It works equally well with any type of instrument approach system.

A partial installation of this all-weather approach light system has been tested at the Cleveland Municipal Airport. The first full system is to be installed at New York City's Idlewild Airport.

Transit Data. Some interesting statistics are outlined in "Transit Fact Book, 1947" issued by the American Transit Association, New York, N. Y. Consumption of electric energy by the transit industry last year reached a total of 6,791,000,000 kilowatt-hours according to the annual survey which covers 1,359 urban transit companies. Expanded trolley coach operations in many cities has continued to add to power loads, reaching in 1946 a new high of 447,000,000 kilowatt-hours. The report reveals that |421 new streetcars were delivered during 1946. These only went to cities with populations above 250,000. Deliveries of new trolley coaches, totaling 266 for the year, were made to cities of 50,000–1,000,000 population. Power purchased from outside sources amounted to more than 69 per cent of the total consumption in 1946, while transit companies generated the remaining 31 per cent. A record total of almost 23.5 billion passengers paid $1,397,100,000 in fares. However, the report states that the operating income of the transit companies declined 6.78 per cent over 1945, due largely to heavy increases in wages and other operating expense. Preliminary figures for the first few months of 1947 showed small declines in operating revenue, while operating expenses continued to rise primarily because of additional wage increases.

Fluorescent Lighted Car Operating in New York Subway

The first of approximately 650 new subway cars (*EE, June '47, pp 547–9*) to be illuminated entirely by cold-cathode fluorescent lighting was put into operation recently on the New York IND subway division. Fluorescent tubes extend down the entire length of the car on each side along the convex edges of the ceiling, while an additional strip, interrupted only by stanchions and electric fans, is installed along the center line of the ceiling.

The model car contains 24 72-inch cold-cathode lamps which are protected by directional-type glass diffusing panels. Operation is on 600-volt direct current, and each lamp including resistive ballast consumes approximately 69 watts. Output of the new lights is rated at 22 lumens per watt (without ballast) to give approximately 19 foot-candles of light at the reading plane. Compared with the old IND car, an increase of 100 per cent in lumen output is obtained for increase of 65 per cent power consumption. Brightness of the lamps is approximately one candle per lineal inch in comparison with the 40 candles per square inch of an ordinary incandescent bulb thereby producing more uniform illumination. In order to provide a high percentage of light reflection, the interior of the new car is painted in light colors.

Sylvania photo

Fluorescent lighted subway car

Destination signs, which are placed above the car windows at a better reading height and free from obstruction, are lighted by concealed green color cold-cathode lamps.

The 72-inch instant-starting cold-cathode lamp developed for this and subsequent cars by Sylvania Electric Products, Inc., New York, N. Y., has an average rated life of 8,000 hours independent of starting frequency occasioned by current breaks when the train passes over third rail gaps at section breaks and cross-overs. A reversing switch is installed in each car to reverse the polarity of the lights daily to prevent darkening of the lamps at the anode end as caused by operation on direct current.

Fixed resistance is used in the circuit in place of two small ballast lamps because the variation in light output due to voltage variation is not sufficient to warrant added maintenance which might be entailed by the use of the small ballast lamps and sockets. Voltage fluctuations are of relatively short duration although the swing may be large, ranging from a low of 400 volts to as high as 750 volts.

R. H. Fair Dies. Richard Harvey Fair, 74, former plant operation supervisor of the Northwestern Bell Company in Omaha, Nebr., died on January 1, 1947. He was one of the most widely-known plant men in that territory, and had retired on January 1, 1938, with a service record of almost 42 years. From 1935 to 1937 he was an AIEE vice-president from the North Central District 6.

Needed Inventions Listed by National Inventors Council

For a number of years now, the National Inventors Council has been releasing lists of needed inventions wanted by the various branches of the Armed Forces of the United States. This was especially true during the war, and pertinent portions of these lists have appeared in the pages of *ELECTRICAL ENGINEERING* (*EE, Aug '43, p 380; EE, June '44, p 238; EE, Mar '45, p 129*). The latest list includes 25 needed inventions among which are the following of interest to electrical engineers:

High-voltage rectifier tube. Rectifier tubes are wanted to stand a peak inverse voltage of 10,000, 20,000, 30,000, and 40,000 volts, requiring a filament current of not over 100 milliamperes, and capable of delivering approximately 300 microamperes. The tubes, which should be light in weight and of minimum size, are to be used to operate an electron tube yielding a bright image. A low-voltage battery-vibrator-type power supply is to be used.

Low temperature storage battery. The military need is for storage batteries capable of operation at temperatures as low as minus 50 degrees Fahrenheit with an efficiency sufficient to supply a range of power from the smallest demand of portable infrared equipment to the heaviest of the largest engine self-starter.

Dry photographic developers. A rapid method for the dry development of both negative and print with a minimum of deterioration and discoloration is wanted. Equipment should be simple, rugged, durable, and adaptable to transport and operation in truck trailers.

Prevention of corrosion. The solution of the problem of fungi and corrosion prevention on all types of material, particularly electric equipment, is of vital importance.

Transmissions. A new smooth power transmission is wanted with infinite variable speed control for railway equipment, including locomotive service up to 700 and 1,300 horsepower.

Ship draft gauge. The Transportation Corps wants a draft gauge to provide accurate readings while the vessel is at sea.

Roll indicator. A recorder of the amplitude and period of rolling is needed to provide accurate information on the stability of a vessel under various conditions of loading and while the vessel is under way at sea.

Fog detector. A device is wanted for an unattended light vessel to start the fog signal when visibility has been reduced to the danger limit. The detector should not respond to ordinary fluctuations of light by day or night.

Oil burner igniter. There is need for a cleaner, safer, more efficient, and positive means than the use of the present standard hand oil torch to light fuel burners on ship's boilers.

Miniature radio sender. This device is needed for use on life-saving flotation equipment as an aid in locating a wrecked ship by means of a signal to aircraft and surface vessels.

Fume detector. There is an urgent need for a combustible gas alarm as a warning device against bilge explosions on gasoline-engine-propelled boats.

All suggestions will be studied by the National Inventors Council and those approved will be sent to the proper branch of the Army, Navy, or Coast Guard. More detailed information can be obtained by writing to the National Inventors Council, United States Department of Commerce, Office of Technical Service, Washington, D. C.

RPI Reported Largest School of Kind

By next fall Rensselaer Polytechnic Institute, Troy, N. Y., will be the nation's largest privately endowed school of science and engineering, exclusive of graduate and evening students, according to a report of President Livingston W. Houston delivered at the annual meeting of the Rensselaer Alumni Association. Enrollment in September will exceed 4,500 students, which is three times the prewar level.

Gifts totaling $487,945 received during the year were reported—$213,876 in funds and the remainder in property and laboratory equipment. Research projects in the fields of metallurgy, biology, chemistry, and aeronautics costing about $250,000 are under way for the Army and Navy.

Revision Announced for NEMA Motor Standards. A second revision, consisting of revised printed pages, recently has been issued for the NEMA Motor and Generator Standards, Publication *45–102*. Standards of particular interest cover the new "*D*" flange, the resistance method of temperature determination, integral-horsepower hermetic motors, and small-power motors for special applications. Purchasers of publication *45–102* (price $4), which includes all NEMA Standards that have been issued for motors and generators, will receive all revisions without charge until further notice. A separate publication excerpting the small-power motor standards included in the standards is in the process of being printed, and orders now are being accepted.

Cleveland Street Lighting Program. In an effort to help city planning, the Greater Cleveland Safety Council street lighting subcommittee has outlined a 3-step procedure before recommending street lighting improvements in Cleveland. The first step will be classification of streets conforming to the light code of the Illuminating Engineering Society. The second step calls for a study of comparative light deficiencies on streets classified. Finally, a priority list of streets to be improved will be prepared. The list will be based on considerations of traffic volume, accident facts, and crime incidents, and when the data are assembled, the group will convey its recommendations to the City Council.

West Virginia Steel Mill Reputed World's Fastest

Westinghouse Electric Corporation engineers designed the motors and electrical control apparatus installed on what is reputed to be the world's fastest steel mill operating in the Weirton Steel Company plant, Weirton, W. Va. The motors drive the mill nearly three times as fast as the majority of strip mills now in operation. The six mill and reel motors are o greater capacity than any previously used in cold strip mill construction as they have a total output of 17,550 horsepower. The 4,500-horsepower unit that delivers the finished product from the last stand is the largest ever used on such a project.

Each motor required individual design to co-ordinate the five sequences of speed necessary for over-all operation of the mill. Steel feeding into the mill passes through the first of five sets of rolls at approximately 650 feet per minute. It then goes through a series of increasingly rapid rolls operating at 1,100, 2,100, 3,200, and 5,000 feet per minute. This output can be increased to a maximum speed of over a mile a minute. Tensiometers between each of the five stands of the operation indicate tautness of the strip metal. Speed is increased or decreased as necessary.

General Motors Exhibits Train of Tomorrow

General Motors Corporation has built a new type of railway train which it calls "The Train of Tomorrow." Its various features are being exhibited on a 6-month nation-wide tour which will take the train to more than 30 leading cities in America.

The experimental unit includes a diner sleeper, coach, and observation lounge car

each having an "Astra-Dome" observation space for 24 passengers and a varied floor level design that makes it quite different from anything previously operated on rails.

The train features an all-electric kitchen, a train-to-home telephone, wire-recorded entertainment, a new type of outside swing hangar springing system which minimizes bumpiness and side-sway, and specially developed journals which also contribute to easier riding. The "Astra-Dome" feature is an observation space enclosed in heat-resistant nonglare glass.

An independent Diesel power system is used for each car, supplying electric power to individual cars on the train for air-conditioning, lighting, and refrigeration. The novel power-package permits a car to be uncoupled from the train without any reduction in electric power. It also makes for constancy of illumination regardless of the speed of the car or the presence of other loads on the lighting system.

JOINT ACTIVITIES

Plans Announced for National Electronics Conference

Doctor George D. Stoddard, new president of the University of Illinois, Urbana, Ill., and one of the nation's foremost educators, will deliver the keynote address at the National Electronics Conference which will be held at the Edgewater Beach Hotel, Chicago, Ill., on November 3–5, 1947. Walter Evans, vice-president of Westinghouse Electric Corporation, will speak at the Monday luncheon, and AIEE President Blake D. Hull will be present at the AIEE luncheon on Tuesday.

A very comprehensive technical program has been arranged, with practically all fields of interest being covered. Major emphasis will be on industrial electronics, and in this connection three sessions in this field will be held. One of these sessions is being arranged by the AIEE in connection with the Midwest general meeting which will be held the same week.

Various new types of antennas, including aircraft antennas, will be discussed. One session will be devoted to commercial, frequency modulation, and television broadcasting, and another to color television and oscillography. Several papers will be presented on instrumentation, and a panel discussion on electronics research operations led by experts in the field has been planned.

Of general interest will be such subjects as guided missiles, electronic computers, supersonics and infrared, microwaves, and detection of particles. Technical details of the new dynamic noise suppressor, invented by Hermon Hosmer Scott (M'38) will be released, and other papers on audio frequencies have been scheduled. A group of educational exhibits by various manufacturers will add interest to the conference.

The complete program for the conference includes 20 technical sessions with a total of about 50 papers, two luncheons, and the main banquet, in addition to the general session on Monday morning.

OTHER SOCIETIES •

EJC Publishes Papers for Latin America

Adelantos de Ingenieria, a new engineering quarterly which reprints selected articles from various engineering journals, was sent recently to the engineering societies and associations throughout Latin America. This quarterly publication of a selected list of recent articles from North American engineering journals is planned to serve the engineers in the other American republics by making available current articles which are believed to be of greatest interest to them. It is a co-operative project of the National Research Council, through its division of engineering and industrial research, and represented by its chairman, Dean F. M. Feiker of George Washington University, Washington, D. C.; the Inter-American Development Commission, represented by M. D. Carrel, projects director; and the Engineers Joint Council through its committee on international relations and more particularly its commission on Latin America, represented by its chairman, Dean S. S. Steinberg of the University of Maryland, Baltimore.

The first issues are experimental in nature and subject to such modifications as may be desirable to make the publication of maximum usefulness to our professional colleagues who receive it. The task of selecting the articles and arranging for their reproduction is being accomplished by the following subcommittee which deserves much credit for the time and effort it has put into the project to make it successful: Chairman Lloyd J. Hughlett, managing editor, *Ingenieria Internacional;* D. D. King, editor, American Society of Civil Engineers; E. H. Robie, editor, American Institute of Mining and Metallurgical Engineers; George S. Stetson, editor, American Society of Mechanical Engineers; G. Ross Henninger, editor, American Institute of Electrical Engineers; and F. J. Van Antwerpen, editor, American Institute of Chemical Engineers.

New Officer for Physics Society. Cleveland Norcross, at present executive secretary of the Office of Scientific Research and Development, has been appointed assistant director of the American Institute of Physics. The institute, in creating the post of assistant director, is recognizing and providing for the increased responsibilities and activities which physicists and their organization now are called upon to undertake in co-operation with government, industry, education, and other professional fields.

Future Meetings of Other Societies

American Chemical Society. 112th national meeting, September 15–19, 1947, New York, N. Y.

American Institute of Chemical Engineers. Annual meeting, November 9–12, 1947, Detroit, Mich.

American Institute of Mining and Metallurgical Engineers. Regional meeting, September 29–October 1, 1947, Denver, Colo.

American Society of Civil Engineers. Fall meeting, October 15–18, 1947, Jacksonville, Fla.

American Society of Mechanical Engineers. Fall meeting, September 1–4, 1947, Salt Lake City, Utah.

American Society of Tool Engineers. 16th annual meeting and tool exhibition, March 15–19, 1948, Cleveland, Ohio.

American Standards Association. Annual meeting, October 21–23, 1947, New York, N. Y.

American Transit Association. Annual convention, October 8–10, 1947, Atlantic City, N. J.

American Welding Society. Annual meeting, October 20–24, 1947, Chicago, Ill.

Association des Ingénieurs. Centenary congress and exhibition, August 30–September 13, 1947, Liége, Belgium.

Association of Iron and Steel Engineers. Annual meeting, September 22–25, 1947, Pittsburgh, Pa.

Canadian Institute of Radio Engineers. Convention, April 30–May 1, 1948, Toronto, Ontario, Canada.

CIGRE (International Conference on Large Electric High-Tension Systems). Biennial meeting, June 24–July 3, 1948, Paris, France.

Conference on Electrical Insulation. Meeting, September 24–27, 1947, at the Massachusetts Institute of Technology, Cambridge, Mass.

Exposition of Chemical Industries. 21st annual exposition, December 1–5, 1947, New York, N. Y.

Fluorescent Lighting Association. Cold cathode fluorescent lighting exhibit, October 7–9, 1947, New York, N. Y.

Illuminating Engineering Society. Annual convention, September 15–19, 1947, New Orleans, La.

Institute of Radio Engineers. West coast IRE convention, September 24–26, 1947, San Francisco, Calif.

Instrument Society of America. Second national conference, September 8–12, 1947, Chicago, Ill.

International Lighting Exposition and Conference. November 3–7, 1947, Chicago, Ill. Sponsored by National Electrical Manufacturers Association.

International Municipal Signal Association, Inc. 52d annual meeting, September 29–October 2, 1947, Grand Rapids, Mich.

National Association of Manufacturers. 52d Annual Congress of American Industry, December 3–5, 1947, New York, N. Y.

National Electrical Contractors' Association. 46th annual meeting, September 8–10, 1947, San Francisco, Calif.

National Electrical Manufacturers Association. October 27–31, 1947, Atlantic City, N. J.; winter convention, March 14–18, 1948, Chicago, Ill.

National Electronics Conference. November 3–5, 1947, Chicago, Ill.

National Machine Tool Builders' Exhibit. September 17–26, 1947, Chicago, Ill.

National Safety Congress and Exposition. 35th annual meeting, October 6–10, 1947, Chicago, Ill.

Pacific Chemical Exposition; Pacific Industrial Conferences. October 21–28, 1947, San Francisco, Calif.

Refrigeration Equipment Manufacturers Association. All-Industry Refrigerating and Air-Conditioning Exposition, January 26–29, 1948, Cleveland, Ohio.

Detroit Engineering Society Meets. The 11th annual meeting of the Engineering Society of Detroit was held in Detroit, Mich., June 25, 1947, and featured a dinner and dance. Colonel Arthur B. Morrill, internationally known civil engineer, spoke on his recent experiences in a talk entitled "The Changing Orient." A few days earlier, Friday, June 20, 1947, the junior section of the society held its annual meeting. Allen V. Brett, a consulting engineer on land-use problems, spoke on "An Engineering Approach to Social Problems." A moving picture sponsored by the Pennsylvania Railroad, "Clear Track Ahead", also was shown.

IES Gets New President. Rudolf W. Staud is the newly-elected president of the Illuminating Engineering Society, New York, N. Y. He will take office as the 43d president upon the expiration of retiring President G. K. Hardacre's term on October 1, 1947. A well-known figure in the lighting industry, R. W. Staud has been identified actively in industry-wide activities relating to the improvement of practices and the development of higher uniform standards for lighting equipment. He has held the offices of vice-president, director, and chairman of numerous committees of the Illuminating Engineering Society. He is also manager of sales promotion and development and editor of *The Lighting Review and Digest*.

New NEMA Product Group Formed

A new electric product group, comprising 11 companies that manufacture apparatus for induction and dielectric heating, has been announced by the National Electrical Manufacturers Association. The section is defined as encompassing induction and dielectric heating apparatus together with accessories, excluding renewal parts and physiotherapeutic apparatus. Also excluded are motor generator sets and generators except when sold as parts of any complete induction and dielectric heating installation.

The section will set up equipment standards and ratings, and safety requirements, and many other factors effecting greater efficiency, increased production, lower costs, faster deliveries, and improved service in this section of industry. Chairman of the group, known as the induction and dielectric heating apparatus section, is Doctor H. B. Osborn, Jr., sales manager, Tocco Division, The Ohio Crankshaft Company, Cleveland, Ohio. The technical aspects of the work of this section will be handled by a general engineering committee, composed of the outstanding technical personnel in the high-frequency heating field.

A Federal Communications Commission committee, the chief purpose of which is to keep in touch with the FCC on matters of mutual interest, also has been formed. T. P. Kinn (M '44), manager, industrial electronics engineering, Westinghouse Electric Corporation, Baltimore, Md., and K. E. Kjolseth, manager of sales, induction and dielectric section, industrial heating division, General Electric Company, Schenectady, N. Y., have been appointed chairmen of these two committees respectively.

Standardization and Research Stressed at ASTM Meeting

The 50th annual meeting of the American Society for Testing Materials, held in Atlantic City, N. J., focused attention on a number of important activities involving standardization and research in materials. The total registered attendance at the meeting was 1,781, and about 350 meetings of the society's technical committees and 19 technical sessions were held during the week beginning June 16, 1947.

The symposium on load tests to evaluate the bearing capacity of soils was intended to correlate and evaluate the considerable amount of data developed during wartime operations, particularly in connection with air fields. Several technical papers on other problems in this field were presented, including one on the uplift pressures on bridge foundations in clay. Also of interest in the construction field were the several technical papers on measuring entrained air in concrete.

The symposium on insulating oils was concerned with the discussion of intrinsic qualities of an oil and discussion of laboratory tests. In the symposium on synthetic lubricants the fact was stressed that the materials discussed are true chemical compounds which have been blended with additives to give the properties desired.

One of the outstanding features of the meeting was the symposium on rubber testing with its eight papers, which gave a complete picture of the work of private industry and the rubber reserve in perfecting satisfactory methods of determining important properties of natural and synthetic rubbers.

As a result of recommendations by the technical committees, the society approved 43 new tentative specifications and tests, and 70 previously published tentative specifications are to be adopted as formal standards.

Two awards were made at the meeting. The Sanford E. Thompson Award, recognizing an outstanding paper on concrete and concrete aggregates, was presented to William Lerch, manager, applied research, Portland Cement Association, for his paper "The Influence of Gypsum on the Hydration and Properties of Portland Cement Pastes." The other award, the Richard L. Templin Award, which recognizes meritorious contributions describing new testing methods and apparatus, was presented to F. B. Quinlan, metallurgical section, works laboratory, General Electric Company, Schenectady, N. Y., for his paper on "Pneumatic Fatigue Machines."

T. A. Boyd, head, fuel department, research laboratories division, General Motors Corporation, Detroit, Mich., was elected president of the society for 1947–48. J. G. Morrow, metallurgical engineer, Steel Company of Canada, Ltd., Hamilton, Ontario, Canada, is the new vice-president who will serve with the senior vice-president, R. L. Templin, assistant director of research and chief engineer of tests, Aluminum Company of America, New Kensington, Pa.

Cold Cathode Lighting Show. The first annual Cold Cathode Fluorescent Lighting Exhibit, sponsored by the Fluorescent Association, New York, N. Y., is to be held at the Commodore Hotel, New York, N. Y., October 7–9, 1947. The show is designed to introduce cold cathode fluorescent lighting. Invited guests at the exhibit will be architects, utility men, consulting engineers, superintendents, purchasing agents, and others interested in lighting from the application point of view. Cold cathode lighting equipment which is now available will be exhibited, and information will be available to help with problems of evaluating, planning, and designing, good cold cathode lighting installation and specifying and procuring cold cathode equipment.

Management Association Elects Officers

Executives representing every phase of management in United States industry have been elected officers and directors of the American Management Association. John M. Hancock of New York, Lehman Brothers partner and a member of the United States delegation to the United Nations Atomic Energy Commission, was designated chairman of the board of the association. Alvin E. Dodd, president of the association since 1936, was re-elected for a 12th term as chief executive. Harold V. Coes, vice-president, Ford, Bacon and Davis, Inc., New York, will serve as the chairman of the executive committee of the association succeeding Keith S. McHugh, vice-president of the American Telephone and Telegraph Company, who was elected a director.

The association is a group of more than 10,500 industrial and commercial companies and executives concerned with management, personnel, industrial relations, production, finance, insurance, packaging, marketing, and office administration. Each year it elects outstanding executives in these fields to assist in the conduct of meetings, publications, and research aimed at the practical solution of current business problems through a broad exchange of information and experience.

Elected vice-presidents were John Stephens, vice-president, United States Steel Corporation, Pittsburgh, Pa.—personnel and industrial relations; George S. Dively, vice-president and general manager, Harris-Seybold Company, Cleveland, Ohio—production; Murray Shields, vice-president, Bank of Manhattan Com-

pany, New York, N. Y.—finance; E. A. Throckmorton, president, Container Laboratories, Inc., Chicago, Ill.—packaging; R. S. Bass, treasurer, A. E. Staley Manufacturing Company, Decatur, Ill.—insurance; Coleman L. Maze, vice-chairman, department of management and industrial relations, New York University, New York—office management; and W. E. Jones, vice-president, Scranton Lace Company, New York, N. Y.—marketing.

Conference on Electrical Insulation. The Conference on Electrical Insulation will hold a meeting in Cambridge, Mass., (at Massachuetts Institute of Technology) September 24–27, 1947. The program will include extended discussion of semiconductor systems and their applications, and other sessions will be devoted to such subjects as dielectric breakdown and recent trends in cable design. In addition, there will be the usual less formal reports on the recent progress of research in the fields of dielectrics and insulation.

RESEARCH . . . . .

High Speed Camera Developed by GE

A camera with a speed of one-millionth of a second which produces a finished photographic projection within 30 seconds after the picture is taken has been developed by the General Electric Company's general engineering and consulting laboratory, Schenectady, N. Y. Fully automatic with the press of a button, it is part of equipment developed for the rapid testing, by means of electric power surges, of apparatus used in the generation and transmission of electric power. Such tests are made to determine insulation characteristics of new designs, and to assure that equipment under production meets performance specifications.

Used in combination with a cathode-ray oscillograph, the camera photographs a visual indication which appears on the television-like screen when a surge of high-voltage electric power is applied to the equipment under test. As soon as the photograph is taken, the operator pushes a button, thereby setting into action the automatic developing equipment built into the camera. The development cycle is finished in 24 seconds, and the film is moved to another compartment in which a projector reproduces the negative enlarged about ten times on a ground-glass screen.

GE Lightning Center. Construction has begun at General Electric's Pittsfield Works on a high-voltage laboratory which will cost more than $1,000,000. When used with existing company facilities, it will constitute the world's largest man-made lightning center. The new building, scheduled for completion in March 1948, will assume the functions of the present laboratory on experiments in the 10,000,000-volt range. The new plant will meet an increased demand for research facilities to study the phenomena of natural lightning and its effects on electric equipment. Larger than the present laboratory, it will afford greater space to experiment at high voltages on larger equipment, including transformers, lightning arresters, capacitors, and bushings.

Carnegie Tech Synchro-cyclotron. Plans for the 200 million electron volt synchro-cyclotron at the Carnegie Institute of Technology are nearer realization as a result of additional financial support. A contract from the United States Office of Naval Research in support of the cyclotron project, and an offer of equipment at special prices from the Westinghouse Electric Corporation, bring the total value of these latest contributions to $280,000, fulfilling the conditions of the $300,000 appropriation received by the school from the Buhl Foundation of Pittsburgh last December. The Foundation stipulated that its grant be supplemented by subscription of at least $250,000 toward the cyclotron from other sources. The total amount of support received by Carnegie for this project is now $580,000, including the original Buhl appropriation. It is estimated that the synchro-cyclotron plan for Carnegie Institute of Technology will produce energies between 200 to 250 million electron volts.

Lightning Effects Study to Be Renewed

The General Electric Company's high-voltage engineers, headed by J. H. Hagenguth (M '44), will renew their study of lightning effects on the Empire State Building. This will renew a study begun by the company in 1935 under Doctor Karl B. McEachron (F '37) one of the nation's foremost lightning experts, and discontinued during the war.

Sensitive lightning recording devices will be used in an attempt to record lightning data heretofore unattainable. The study is to be limited to instrument recordings at first, however, photographic studies of lightning striking the building, simultaneously timed with oscillographic recordings, also will be renewed when suitable space is found to locate the special lightning cameras.

The Empire State Building originally was chosen for the studies because the high building attracts lightning. The previous studies there, from 1935 to 1941, with both oscillograph and high and low speed cameras, resulted in detailed knowledge of the frequency of lightning strokes, the wave shapes, currents, amplitudes, and other significant scientific data.

Some of the more interesting information discovered was that about 80 per cent of the strokes to the building originated at the top of the Empire State Building, and were fired into the sky. This happened when the building absorbed an excess of positive currents from the earth. Another significant discovery was that not all lightning strokes produce thunder. None of the strokes from the building to the sky was followed by thunder. It also was found that current persisted as long as a second and a half in some cases. The data sought now not only will add to man's understanding of lightning phenomena, but will improve his ability to reproduce natural lightning in the laboratories. This is important in the development of improved lightning protective equipment for the electrical and other industries.

Research Director Appointed. Doctor Edwin G. Schneider, formerly assistant to the president for research at Stevens Institute of Technology, has been appointed director of a comprehensive program of research on controlled flight, including flight at supersonic speed, at the Massachusetts Institute of Technology, Cambridge. He is widely known for his research on television tubes, radar, the optical properties of solids in the extreme ultraviolet, and secondary electron emission.

Iowa State College Building Synchrotron. The group of colleges and universities which are expanding their efforts in the nuclear research field now includes Iowa State College, Ames. A 70,000,000-electron-volt synchrotron is contemplated. It will duplicate in size and energy the unit at the General Electric Research Laboratory, Schenectady, N. Y., the only synchrotron now in operation in this country. Components will be built by the general engineering and consulting laboratory of General Electric Company, and installation and operation of the machine will be one of the activities of the Iowa State College Institute for Atomic Research directed by Doctor F. H. Spedding. It will be used jointly by members of the college's physics, chemistry, and electrical engineering departments. First application planned for the unit is the study of nuclear reactions produced by high energy X rays from the machine.

Cyclotron Oil. Considerable heat is produced in the generation of the magnetic field of a cyclotron. To dissipate this heat, a special cyclotron oil was developed by Gulf Oil Research laboratories of the Gulf Oil Corporation. It is designed to withstand the catalytic action of the large amounts of copper used in cyclotron production of radioactive elements. Initial application of the new oil is being made in the recently completed cyclotron of the University of Pittsburgh, Pittsburgh, Pa.

HONORS

ASME Confers Awards at Semiannual Meeting

Three midwesterners were honored by the American Society of Mechanical Engineers during the semiannual meeting held in Chicago, Ill., June 15–19, 1947. The awards were conferred at a banquet held at the Hotel Stevens, which was attended by more than 1,000 engineers and their guests.

James H. Herron, president of the James H. Herron Company of Cleveland, Ohio, cited for 50-year membership, is a Fellow and past president of the American Society of Mechanical Engineers. He is the inventor of numerous devices for air compressors and metallurgical furnaces now in practical use, and is the author of many technical articles.

John T. Faig, similarly honored, is president of departments of the Ohio Mechanics Institute, Cincinnati, and a Fellow of the society. He is a leader in engineering education and served on the commission which drafted Cincinnati's smoke abatement laws.

Martin Goland, chairman of the engineering mechanics section of the Midwest Research Institute, Kansas City, Mo., received the Alfred Noble prize certificate and cash award, given annually to a member of one of the four founder engineering societies, under 30 years of age, for a paper of merit. The prize fund was set up by the late Alfred Noble, president of both the Western Society of Engineers and the American Society of Civil Engineers, which administers the prize. Mr. Goland's paper is entitled: "The Flutter of a Uniform Cantilever Wing." He holds the ASME Junior Award and the Spirit of St. Louis Medal also.

Bateman Honored by Cooper Union. Dean George F. Bateman of the Cooper Union school of engineering, at commencement exercises on June 5, 1947, was awarded a certificate for meritorious service in recognition of his 40 years on the Cooper Union faculty. He is well known in professional circles, and has been active in many professional and technical organizations including the American Society of Mechanical Engineers, the library board of the United Engineering Societies, the New York Electrical Society, the Society for the Promotion of Engineering Education, and the Engineers Council for Professional Development.

Steel Plants Win Safety Award. The National Safety Council's highest award to industrial firms has been won by 12 plants of the Carnegie-Illinois Steel Corporation, a United States Steel Corporation subsidiary. Each of the plants was awarded a Distinguished Service to Safety Award for operating without a single lost-time accident over a combined period of 25,000,000 man-hours of working time. According to the National Safety Council, this is one of the best safety records in years among heavy industrial organizations.

L. D. Gardner Wins 1947 Daniel Guggenheim Medal

The 1947 Daniel Guggenheim Medal given for notable achievement in the advancement of aeronautics has been awarded to Lester D. Gardner of New York, N. Y. The selection of the recipients for this highest American aeronautical honor is made by a board of 21 members consisting of the former recipients of the medal and representatives of the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the Institute of the Aeronautical Sciences.

The medal and a certificate were awarded "for outstanding achievements in advancing aeronautics, particularly for his conception and organization of the Institute of the Aeronautical Sciences." In 1932 Mr. Gardner organized the institute and was chairman of its council and president of the aeronautical archives until his retirement this year.

ASCE Announces New Annual Award. A new annual award, to be made by the American Society of Civil Engineers in honor of the late Leon S. Moisseiff, New York consulting engineer and one time bridge engineer and engineer of design for the New York City Department of Bridges, has been announced by the American Society of Civil Engineers. The Leon S. Moisseiff Memorial Committee offers a sum of $4,000 to perpetuate the memory of Mr. Moisseiff. The award, a bronze medal and an appropriate certificate signed by the president and executive secretary of the society, will be made for an important paper dealing with the broad field of structural design, including applied mechanics, as well as the theoretical analysis, or constructive improvement, of engineering structures such as bridges and frames of any structural material. The award will be open to nonmembers as well as to those who are members of the American Society of Civil Engineers.

C. A. Thomas Wins Industrial Research Medal. The second presentation of the Industrial Research Institute's Medal was made to Charles Allen Thomas, executive vice-president, Monsanto Chemical Company, for his pioneering and inspiring leadership in the development of the American industrial research system, and for his participation thus in American chemical enterprise. The award was made at the ninth annual meeting of Industrial Research Institute on June 5–6 in Swampscott, Mass.

FOREIGN

Eight Year Plan Devised to Develop Indian Broadcasting

An 8-year plan, which will form the first stage of the development of broadcasting in India, has been reported in the June 28, 1947, issue of *Foreign Commerce Weekly*. The main features of the plan are as follows:

1. Construction of studio buildings at Madras and Calcutta, as well as provisions of additional office accommodation and studio facilities at existing broadcasting centers.
2. Installation of eight high-power medium-wave transmitters for urban programs; two each at Bombay, Calcutta, Madras, and Delhi.
3. Installation of three 20-kw medium wave transmitters for rural programs; one each at Bombay, Calcutta, and Madras.
4. Installation of two high power and one 20-kw medium wave transmitters at Allahabad.
5. Installation of 20-kw medium wave transmitters; one each at Karachi, Nagpur, Hezwada, Ahmedabad, Cuttack, Dharwar, Gauhati, and Calicut.

The 8-year plan has been approved by the standing advisory committee attached to the information broadcasting department of India. The new transmitters will be installed as and when necessary equipment and staff become available. The government of India will not permit the broadcasting of commercial advertising, and no provision is being made as yet for television. In addition, private companies will not be allowed to set up broadcasting stations, and, unlike the British Broadcasting Corporation, all Indian radio will not be turned into a public corporation by the government.

Mexico—Communications System. According to the American Embassy at Mexico City, the Telefónica Nacional of Mexico has inaugurated a new carrier system which will facilitate the transmission of telegraph messages and long-distance telephone calls. The system has two direct lines between the city of Mexico and Nuevo Laredo, touching at the cities of Queretaro, San Luis Potosi, and Monterrey. Three telephone calls can be carried on at the same time without voice interference, and as many as 14 telegraph messages from one direction and the same number from the other may be transmitted simultaneously. Similar apparatus is expected to be provided in other important cities of the republic in the future. (*Foreign Commerce Weekly.*)

Argentina—National Power System. The first construction under the government's plan for a national power system was started in May 1946 at Lujan de Cuyo, Province of Mendoza, on the hydroelectric power plant there. It was reported in October that the government was negotiating for the purchase of large American electric-

power holdings in the country. Two power companies in the city of Cordoba, owned by American interests, were taken over on November 12 by the provincial government. (*Foreign Commerce Weekly.*)

Chile—Utility Rates Rise. Electric light and power rates were increased about 30 per cent effective April 1, 1947, in the Santiago and Valparaiso districts, and an increase of 20 per cent in telephone rates for all Chile was made effective May 1 by decrees published April 17, 1947, in the *Diario Oficial.* (*Foreign Commerce Weekly.*)

Argentina—Telephone Company Sold. The United River Plate Telephone Company, subsidiary of International Telephone and Telegraph Company, was purchased by the Argentine government in October for $94,991,000 cash. This was the largest single United States utility holding in Argentina. A semiofficial company, composed of government and private capital, was organized under the name of Empresa Mixta Telefónica Argentina (EMTA) to take over this telephone system. (*Foreign Commerce Weekly.*)

Austria—Railroad Electrification. The program of electrifying the state railroads, started in the United States zone of Austria in the summer of 1946, is the beginning of a 12-year project which, when completed, will result in the electrification of the remaining steam-operated main lines in Austria. The program is self-liquidating with a two-fold purpose—to enable Austria to reduce imports of coal and to revive the country's electric equipment manufacturing industry. (*Foreign Commerce Weekly.*)

Great Britain—BBC Gets Frequency Modulation. A significant development in the history of British broadcasting is marked by the announcement that Marconi's Wireless Telegraph Company, Ltd., is supplying a 25-kw frequency-modulated transmitter to the British Broadcasting Company. It is the first of its kind to be put in service by the BBC. (*Foreign Commerce Weekly.*)

Turkey—Radio Stations Authorized. Authorization has been given for the construction of two radio stations in Anatolia, Turkey, in addition to the two now under construction at Istanbul and Ankara. Contracts were awarded in January 1946 for a 100-kw short wave station in Ankara and a 150-kw medium wave station in Istanbul. The work at Istanbul will not be completed until the end of 1947. Operating at a frequency of 758 kc, this station reportedly will be the most powerful medium wave station in Europe outside Russia. Radio subscribers in Turkey, all of whom have licenses, reached a total of 178,000 at the end of 1945, an increase from 46,244 at the end of 1938. (*Foreign Commerce Weekly.*)

Finland—New Power Plant. A program for the construction of new power plants that will bring the yearly production of electric energy up to 4,300,000,000 kilowatt-hours in 1951 was outlined in a recent speech by U. Raade, chief for the industrial division of the Ministry of Commerce and Industry in Finland. Present production is about 2,500,000,000 kilowatt-hours annually. (*Foreign Commerce Weekly.*)

France—Broadcasting Facilities Grow. On October 1, 1946, France had 42 radio stations with a total power of 683.85 kw broadcasting on 25 frequencies. This represented an increase of 25 per cent in the number of stations since January 1 of that year and an equivalent power increase. The power output of stations Lyon-Travoyea, Marseille-Realtor II, and Bordeaux II will be increased shortly. These increases, together with the opening of a station at Ennezat, will bring the total power of all stations operating on medium wave to 881.85 kw. To conserve frequencies, and at the same time cover as great an area as possible, certain stations are being synchronized and lower power relay stations are being used in connection with broadcasts to certain areas. (*Foreign Commerce Weekly.*)

Spain—Powerful Radio Station. A 200-kw radio station is being constructed on the Spanish African Island of Fernando Po. This is reputed to be the world's most powerful commercial radio station. Built by the Spanish Inter-Continental Broadcasting Company under a license granted by the government in January, the station will have four beams directed to Europe, Africa, United States, and South America. The plans call for broadcasts in Spanish, English, German, Portuguese, Italian, and French, and time will be sold to any commercial user. The station is equalled in power only by two American government stations on the west coast.

Sweden—Hydroelectric Power Expansion. A program is under way to expand Sweden's hydroelectric power production by 1,000,000 kw. It is estimated that the increase in production will reach about 50,000 kw in 1947, because of the additional power supplied by the new turbines installed at Namsorsen. By 1950 the annual production should reach 16,000,000,000 kilowatt-hours. Among the power plants under construction are: Harspranget at Lulealven, which will be the largest in Sweden and which will have an annual capacity of 260,000 kw; Hollaforsen at Indalsalven, 127,000 kw; expansion of the Hjalta plant at Faxalven, 120,000 kw; and Forsmo at Angermanalven, 74,000 kw. More than a dozen existing stations are marked for expansion. If the electrification of Sweden's rural areas proceeds at the same rate as during World War II, it is expected that 95 per cent of all rural households will be supplied with electricity within five years. This compares with the present rate of 85 per cent rural electrification. (*Foreign Commerce Weekly.*)

Great Britain—Radio Exhibition. Radiolympia—National Radio Exhibition, is to be held in London on October 1–11, 1947. Inquiries should be addressed to the Radio Industry Council, 59 Russell Square, London, W. C. 1, England.

India—Hydroelectric Projects. Three proposed South Indian hydroelectric projects are estimated to cost some $307,500,000. They are Ramapadasagar ($258,000,000), Tungabhadra ($25,500,000), and Machkand ($24,000,000). This total exceeds the cost of projects in all the rest of India, which is estimated at a total of $237,000,000. American participation already has begun to take shape in South India. (*Foreign Commerce Weekly.*)

EDUCATION • • •

Kodak Fellowships Offered for 1947–48

Sixteen educational institutions have been offered one or more of 22 Eastman Kodak fellowships in chemistry, physics, engineering, and business administration for the school year 1947–48 (*EE, June '47, pp 623–4*). In addition, six similar fellowships are to be sponsored by Tennessee Eastman Corporation, an Eastman Kodak subsidiary. The fellowships were established by the company in 1939 to enable outstanding young scientists to continue their advanced studies in scientific and engineering fields. Since then they have been offered each year with the exception of 1944–45.

Twelve of the Kodak fellowships are for doctoral work. Of these, each valued at $1,200, one in physics and one in chemical engineering will go to the Massachusetts Institute of Technology, Cambridge. One each will go, in physical chemistry, to Columbia University, New York, N. Y.; University of Rochester, N. Y.; and Yale University, New Haven, Conn.; in organic chemistry, to Harvard University, Cambridge, Mass.; University of Illinois, Urbana; University of Nebraska, Lincoln; and University of Notre Dame, South Bend, Ind.; in physics, to California Insti-

tute of Technology, Pasadena; University of Michigan, Ann Arbor; and University of Wisconsin, Madison.

Ten fellowships for master's work, each worth $750, have been offered as follows: in business administration, Columbia University, University of Michigan, University of Illinois, and Northwestern University, Evanston, Ill.; in mechanical engineering, Carnegie Institute of Technology, Pittsburgh, Pa.; and Iowa State University, Iowa City; in electrical engineering, Cornell University, Ithaca, N. Y.; and Rensselaer Polytechnic Institute, Troy, N. Y.; in chemical engineering, Cornell University and University of Michigan.

The six Tennessee Eastman awards include four at $1,200 for doctoral work in chemistry at Brown University, Providence, R. I.; University of Tennessee, Knoxville; University of North Carolina, Chapel Hill; and University of Virginia, Charlottesville. Two for master's work at $750 are in chemical engineering at Virginia Polytechnic Institute, Blacksburg; and in textile engineering at Georgia School of Technology, Atlanta.

The fellowships carry no provision requiring the recipients subsequently to work for the company. Selection of the students is made by the university where the fellowship is awarded. The only qualifications prescribed by the company are that the student must be in the last year of graduate training for his degree, must possess demonstrated ability in his major field, a high degree of professional or technical promise, soundness of character, and financial need.

New President at Case Institute. T. Keith Glennan, executive of Ansco Division of General Aniline and Film Corporation, Binghamton, N. Y., and wartime director of the United States Navy Underwater Sound Laboratory, has been appointed president of Case Institute of Technology, Cleveland, Ohio. He will be the first business executive to head the Cleveland engineering school, which has had but three presidents since its establishment 67 years ago as the Case School of Applied Science, and which adopted its new name on July 1, 1947. He succeeds Doctor William E. Wickenden who retires on September 1, 1947, after 18 years of service.

Quality Control Course Offered By University of Iowa

An intensive 10-day course in quality control by statistical methods is announced by Dean F. M. Dawson of the college of engineering and chairman of the committee on quality control, and by Dean Earl J. McGrath of the college of liberal arts at the State University of Iowa, Iowa City. The course will be given October 28 to November 7, 1947, inclusive.

This is the fifth quality control course to be offered by the University of Iowa. The tuition, including books and supplies, will be $100. Trainees will be expected to provide for their own living expenses and transportation to and from Iowa City. The number of trainees in the course will be limited.

Those desiring to submit nominations for themselves or for representatives of their organization to attend the course in October, or those interested in additional details, should write directly to Professor Lloyd A. Knowler, Department of Mathematics, State University of Iowa, Iowa City.

Stevens Adds New Buildings. Two new buildings, costing approximately $700,000, are being added to the Science Center at the Stevens Institute of Technology, Hoboken, N. J. The Kidde Memorial Laboratory of Physics and the Peirce Memorial Laboratory of Metallurgy will be 3-story brick and steel structures. They will provide much needed classroom space for the whole Science Center. The buildings are named in honor of Doctor William H. Peirce, a Stevens graduate (1884), vice-president of the American Smelting and Refining Company and a pioneer in the electrolytic refining of copper, who died in 1944; and Doctor Walter Kidde, also a Stevens graduate (1897), a trustee of the college for 30 years and chairman of the board for 8 years, and who also was president of the Walter Kidde Company and Walter Kidde Constructors, Inc., at the time of his death in 1943.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Energy Flow

To the Editor:

If the engineer placed in Mr. Richter's compartment by Mr. Slepian (*EE, Mar '47, pp 318–19*) is aware of his friends' fondness for practical jokes, I believe he is in no worse a position than if he had entered a compartment through which none of the conductors passed. In either case, he can recognize his plight and make the claim that the problem is incapable of a valid solution.

I see no reason to question Mr. Richter's right to use his interpretation (*EE, June '47, pp 626–7*) of Poynting's theorem in this and in those other cases where the flux line of $E\times H$ form closed loops, as long as he ultimately integrates over closed surfaces to locate and compute the sizes of sources and sinks. The derivation of Poynting's theorem obviously allows this. However, I do believe that an interpretation is desirable which corresponds more closely to the usual concepts of energy flow and does not require the inclusion of a flow which admittedly might be called fictitious.

In the derivation of Poynting's theorem, use is made of certain field equations to provide an expression which can be interpreted as energy flow. Thus the derivation and interpretation of Poynting's vector assumes certain relations between the field functions. For convenience, these relations can be thought of as the definition of an impedance. Unless the fields in question can be shown to satisfy these relations, the engineer, to my mind, is justified in refusing to attach any real significance to his calculations of energy flow.

The situation seems to me to be the same as though the engineer were required to calculate power consumption from a batch of photographs of ammeters and voltmeters which were taken at the same time but thoroughly shuffled after development, or from an ordinary voltmeter and ammeter reading in an a-c circuit about which he had no other information.

If it is found that the field functions satisfy these relations, the calculation of energy flow may be made with confidence. If they do not, it may be found, and in general should be found, if sufficient information is available, that E and H may be written $E=\Sigma E_i; H=\Sigma H_i$ where each E_i and H_i satisfy the requirements in pairs. This is true in the cases given in the two letters referred to in the foregoing. In these instances, we are justified in writing Poyntings vector either in the form

$$P=\Sigma E_i\times H_i$$

or

$$P=E\times H-\Sigma E_i\times H_j;\quad i\neq j$$

This has the advantage of disposing of that portion of the "energy" flow which flows in closed loops and therefore does not correspond to any sources or sinks.

In general, to make the investigation regarding the relations between the field functions so that this device may be used, it will be necessary to have access to a sufficient portion of the field boundaries, the portions of the boundaries at infinity being disposed of by the usual methods. In any instance, it should be possible to determine whether an adequate portion of the boundary is accessible, and the engineer in the compartment would not be at the mercy of his colleagues.

The engineer placed in the compartment

may make rather obvious tests of voltage and current (the integrated values of E and H) at and in the conductors available to determine the resistances at various pairs of points, and find out if the observed voltages and currents satisfy the relations so defined. When he finds they do not, he then can holler for more wires in the compartment.

ARGYLE W. BRIDGETT (A '43)

(Associate electrical engineer, Corps of Engineers, United States War Department, Boston, Mass.)

Electrical Essay

To the Editor:

The question in the electrical essay in the May issue may be answered by assuming, for the time being, that there is no burden other than the voltage circuit of the wattmeter. The current in the voltage circuit, at 110 volts, will be twice that in the 220-volt supply line. Therefore, half the current flowing into the voltage circuit is drawn from the transformer winding, through the current coil of the wattmeter, in opposite direction to that in the 220-volt supply line, and the wattmeter will indicate minus six watts. Now add the core loss and the wattmeter will indicate six watts less than half the core loss. Therefore, 2(20+6) equals 52 watts equals total core loss.

R. W. OSBORNE (M '31)

(Director, Osborne Electric Company, Limited, Toronto, Ontario, Canada)

To the Editor:

The error in reasoning in the transformer core-loss problem posed by George V. Mueller as an electrical essay in the May issue follows.

With the wattmeter connected as shown in the essay, the winding that is normally the primary of the transformer becomes an autotransformer with an equal number of turns on each winding of the autotransformer. The open secondary winding of the transformer has no bearing on the following discussion.

The current flow in the autotransformer is as shown in Figure 1 of this letter, and $I_1=I_2+I_3$ vectorially. The winding 1–2 becomes the primary and the winding 3–4 becomes the secondary of the autotransformer. The secondary current, I_2, reverses when the load current, I_3, exceeds twice the transformer exciting current, or for any but the very smallest loads.

As there are an equal number of turns on each winding of the autotransformer, each winding contributes equally to the current in the potential coil of the wattmeter. This means that the current through the current coil of the wattmeter, or the secondary current of the autotransformer, is less than the exciting current for the transformer by one half of the current in the potential coil of the wattmeter, and that the current in the primary winding of the autotransformer is greater than the exciting current by one

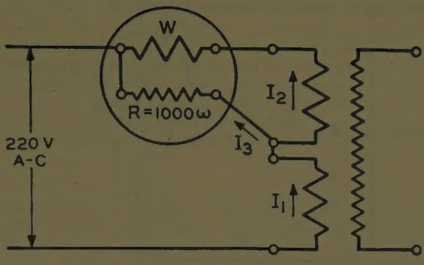


Figure 1.

half of the current in the wattmeter potential coil.

The wattmeter indication, which, when connected as shown in Figure 1, was 20 watts, and the I_2R loss in the wattmeter voltage circuit is 12 watts as stated in the essay, is therefore less than one half of the core loss of the transformer by one half of the I^2R loss in the potential coil of the wattmeter.

Then one half of the transformer core loss should equal the wattmeter indication (20 watts) plus one half of the I^2R loss in the wattmeter voltage circuit (6 watts) or 26 watts, and the total core loss of the transformer should be two times 26, or 52 watts, instead of the 40 watts as reasoned in the essay.

C. W. HOILMAN (M' 42)

(Lieutenant commander, United States Naval Reserve, Navy Department, Bureau of Ships, Washington, D. C.)

To the Editor:

I suggest the following analysis of the electrical essay in the May issue.

With the connections of the potential coil as shown in Figure 1, the current drawn by the potential coil actually must be supplied by the transformer winding; therefore, this current flows through the current coil of the wattmeter thereby representing an apparent increase in power of 12 watts over the power reading of 8 watts, which would be indicated by the wattmeter if the potential coil had been connected directly across one half of the transformer winding. Thus, it should be apparent that the total power drawn by the transformer plus the loss in the potential coil must be equal to two times 8 watts or 16 watts, which is the value that would have been indicated by the wattmeter if a meter having 220-volt potential coil had been used. Thus, subtracting the 12 watts dissipated in the potential coil leaves a figure of 4 watts for the transformer core loss.

WILLIAM T. CARNES, JR.

(Superintendent, radio system staff engineering, Transcontinental and Western Air, Inc., Kansas City, Mo.)

To the Editor:

I think that the correct solution to Professor Mueller's electrical essay (*EE, May '47, p 440*) is as follows.

To neglect the load of the voltage circuit is not correct because, if it is true that from one side such a circuit is connected on the line side of the current coil, from the other it is not connected to the supply line, but to the middle point of the transformer.

By such connection the transformer is acting as an autotransformer, ratio 2:1, loaded with the 12 watts of the voltage circuit. Therefore, the current coil will pass half of the current absorbed by the voltage circuit and directed in such a way as to reduce the reading of the wattmeter.

To the wattmeter reading, therefore, must be added the 12/2 = 6 watts, and the transformer loss will be 52 watts and not 40 watts as published.

GEROLAMO CALABRIA

(Società "Montecatini," Milan, Italy)

To the Editor:

In answer to the electrical essay which appeared in the May 1947 issue I submit the following.

When the engineer neglected the loss in the potential coil of the wattmeter he overlooked two points.

First, the law which requires one less current element than there are conductors feeding into a system to measure all the power.

Second, the action of an autotransformer.

If the transformer had no loss, the current in the potential coil would have two components: One from the line to which the current coil of the meter is connected; the other coming from the transformer through the current coil of the meter in apparently a reverse direction.

As the current in each half of the transformer will be equal and opposite, the current through the meter will cause it to indicate six watts, or half the potential coil loss in a reverse direction.

Therefore, a total direct indication of 20 watts is six watts less than true iron loss indication and the iron loss should be 2 times (6+20) or 52 watts.

MAX PAFENBACH (A '46)

(117 Carson Avenue, Dalton, Mass.)

To the Editor:

Professor Mueller's engineer (electrical essay in May issue) apparently is destined for a certain amount of trouble: (1) he will need a small boy to help carry that wattmeter with the 22½-watt voltage coil; (2) he is measuring copper loss as well as core loss; (3) he is overlooking the unequal division of voltages occasioned by a supposed 1,000-ohm shunt across the measured coil; (4) in the event that he is really after total transformer loss instead of core loss only, he is overlooking the reflected copper loss from the high-voltage coil, which loss would be present under load; (5) he is working for a pretty "chinchy" outfit if it will not provide him with a wider diversity of equipment than that mentioned.

If, perchance, he should decide that his voltage coils actually are rated at 1,000 ohms/volt, total resistance of 150,000 ohms instead of 1,000 ohms, he might be justified in neglecting a much smaller unbalance of voltages than originally anticipated, depending on the required accuracy of measurement. Another alternative would be to obtain an equal division of voltages by means of a voltage divider: for example, one 30,000- and one 25,000-ohm resistor connected in series across the 220-volt supply, with the voltage coil (assuming 1,000 ohms/volt) connected in parallel across the 30,000-ohm resistor. The total transformer loss then would be twice the wattmeter reading. He still will need additional instruments with which to determine his copper loss unless he happens to be a meter expert and revamps the wattmeter so as to utilize the voltage and current coils separately and is able to calibrate them as voltmeter and ammeter respectively.

RICHARD A. WALL (A '41)

(1044 West 93 Street, Los Angeles, Calif.)

To the Editor:

My answer to Professor Mueller's toy problem in the electrical essay appearing in the May issue follows.

Because of the shunting effect of the wattmeter's potential circuit on the one 110-volt transformer winding, such winding will be excited by something less than 110 volts. Hence, the core loss found by multiplying the wattmeter reading by two will be smaller than the true core loss. It would appear expedient to shunt the second winding with a balancing resistor equal in ohmage to the potential circuit resistance, or 1,000 ohms in this particular instance. There then would be no error involved and the wattmeter reading only need be multiplied by two. It is proper to assume the potential circuit of the wattmeter to be a simple resistance load.

C. W. FIELDS (A '31)

(Assistant engineer, electrical engineering department, Consolidated Edison Company of New York, Inc., New York, N. Y.)

To the Editor:

The transformer problem presented by Professor George V. Mueller in the electrical essay in the May issue may be solved easily with the assistance of a redrawn diagram. For the sake of simplicity the secondary winding is omitted and the primary regarded as an autotransformer having a ratio 220/110 volts.

Since we are told that the I^2R loss in the current coil may be neglected, ther pimary winding of the autotransformer may be regarded as being connected directly to the 220-volt supply and the 110-volt secondary winding as having a load of 12 watts resulting from the voltage coil. Being a 2/1 autotransformer, the current in the winding resulting from the load is equal to half

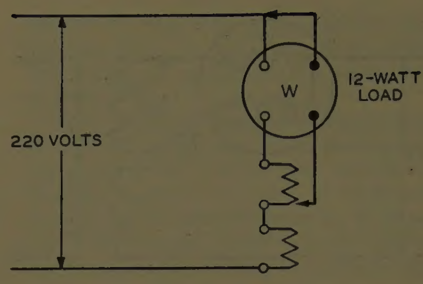


Figure 1.

the current flowing in the load, hence the current in the current coil as a result of the load is equal to half the current actually flowing through the voltage coil. Therefore, the meter reading of 20 watts is made up of 6 watts loss in the voltage coil and 14 watts loss in the transformer. As the voltage coil is connected across half the transformer winding, this figure must be doubled, giving the no-load loss of the transformer as 28 watts.

H. J. HOWARD (A '45)

(Canadian Bank of Commerce, Vancouver, British Columbia, Canada)

To the Editor:

The following is the solution to my electrical essay which appeared in the May issue (*EE, May '46, p 440*).

With the low-voltage coils connected as shown, an autotransformer results in which the voltage circuit of the wattmeter becomes a load across one coil. Of the current in the voltage circuit, one half is supplied from each coil of the transformer. For the transformer coil across which the voltage circuit is connected, the current supplied subtracts directly from the power component of the exciting current. As a result, the wattmeter reads less than one half the core loss by an amount equal to one half the loss in the voltage circuit or by six watts. Hence, the correct core loss is 2 times (20 + 6) = 52 watts.

GEORGE V. MUELLER (M' 35)

(Professor of electrical engineering, Purdue University Lafayette, Ind.)

English Society

To the Editor:

I am reluctant to criticize such a courteous and friendly letter as that from Philip L. Alger (*EE, June '47, p 628*), but it contains one small error which, if it were not corrected, might lead to some misconception of the status of our grades of membership, possibly to the detriment of the members themselves.

Although the penultimate paragraph of the letter outlines in general terms quite correctly the seven classes of membership, subparagraph three of the third paragraph contains a reference to the grade of "Fellow," which possibly makes it appear that the grade of "Member" is the second senior technical grade in The Institution. This is not the case, because the grade of "Member" is the highest and there is no grade of "Fellow."

Comparing our bylaws with your constitution, our grade of "Member" is approximately equivalent to your grade of "Fellow" and our "Associate Member" to your "Member."

My council earnestly desires that our two bodies always should move towards closer understanding between electrical engineers on both sides of the Atlantic and for that reason I welcome the spirit which prompts Mr. Alger's letter, and add that I always shall be happy to supply fuller details of The Institution's constitution and work.

W. K. BRASHER

(Secretary, The Institution of Electrical Engineers, London, W.C.2, England)

NEW BOOKS • • •

"Concise Chemical and Technical Dictionary." Approximately 50,000 definitions are included in this volume which covers almost every scientific and technical field such as chemical, manufacturing, industrial, biological, mathematical, medical, and engineering. Many cross-references make the dictionary practical and easy to use. A special feature is an up-to-date compilation of thousands of trade names of proprietary products. General rules for pronunciation of chemical terms recommended by the American Chemical Society, and a list of key words with their phonetic spellings is a feature of unusual value. A section is devoted to tables for conversion factors, indicators, organic ring systems, chemical elements, vitamins, and Greek letter symbols. Also included are up-to-the-minute addenda sheets which list the newest trade names and definitions of additional technical terms. By H. Bennett. Chemical Publishing Co. Inc., 26 Court Street, Brooklyn 2, N. Y., 1947, 1,055 pages, 6 by 9 inches, $10.

"The Strange Story of the Quantum." The history of the discovery of the composition of the atom dating back to an experiment in 1887 by Heinrich Hertz is presented in an absorbing manner with many simple analogies from familiar objects. Discovery of the quantum by Max Planck in 1900 as a solution to the "violet catastrophe" touched off an exciting round of events. Einstein's theory of the photoelectric effect, not so well known as his theory of relativity, is described as one of the many ideas put forward concerning the particle or wave nature of electromagnetic radiation. The battle between the theories as to the nature of electromagnetic radiation is prominent throughout the book. Evolution of the theory of composition of matter and energy from its earliest concepts to its present one involving electrons, protons,

photons, positrons, neutrons, neutrinos, and mesons is treated to its present stage of development. By Banesh Hoffmann., Harper and Brothers, New York, N. Y., 1947, 239 pages, cloth bound, $5^1/_2$ by $8^1/_4$ inches, $3.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ELECTRIC CONTACTS. By R. Holm. Almqvist and Wiksells Akademiska Handböcker, Hugo Gebers Förlag, Stockholm, Sweden, 1946. 398 pages, illustrated, diagrams, charts, tables, $9^1/_2$ by 6 inches, cloth, apply. (45 Swedish crowns, about 62S.) This book presents a detailed study of the physical principles of contact phenomena, including all fundamental formulas, with a large amount of tabular and graphic data. The three main parts deal respectively with stationary contacts, sliding contacts, and electric phenomena in switching contacts. In the section on sliding contacts, considerable space is devoted to the question of mechanical friction and wear. The description of circuit-breaker phenomena is limited chiefly to weak currents. There is a 25-page bibliography.

ELECTRONS (+ and −), PROTONS, PHOTONS, NEUTRONS, MESOTRONS, AND COSMIC RAYS. By R. A. Millikan. Revised edition 14M. University of Chicago Press, Chicago, Ill., 1947. 647 pages, illustrated, diagrams, charts, maps, tables, $7^1/_2$ by 5 inches, cloth, $6. Continuing the expansion of the author's original small work, "The Electron", this new edition replaces the last 50 pages of the previous edition by some 200 pages of new material under the following headings: release and utilization of nuclear energy; geomagnetic studies on cosmic rays at low altitudes; discovery and significance of the mesotron; nature and number of the incoming primary rays; and the atom-annihilation hypothesis as to the origin of cosmic rays. The first 400 pages, dealing with the progressive developments in atomic theory, the mechanism of ionization, waves and particles, the neutron, and the release of nuclear energy, remain much the same except for the addition of new knowledge such as values of units.

GENERATORS AND MOTORS AND THEIR APPLICATIONS. By D. J. Duffin. McGraw-Hill Book Company, New York and London, 1947. 210 pages, illustrated, diagrams, charts, tables, 10 by $7^1/_4$ inches, cloth, $4. This manual, for on-the-job use by armature winders and electric-motor repairmen, presents fundamental motor and generator theory. It provides important working data on a wide variety of types and makes of a-c and d-c equipment. Clear-cut external, sectional, and disassembled views of machinery add to its practical value. This first of a projected series of three manuals also contains information on selection, applications, maintenance, and trouble shooting.

MODERN TELEGRAPH SYSTEMS AND EQUIPMENT. By W. T. Perkins. George Newnes Ltd., London, 1946. 215 pages, illustrated, diagrams, charts, tables, $7^1/_2$ by 5 inches, cloth, 10s/6d. Important developments in telegraph technique during the last decade are described for the use of telecommunication engineers, traffic officers, and students in electricity and radio-communication. These developments cover voice frequency, telex, sub-audio, and varioplex systems, and all types of modern apparatus such as the teleprinter, teletypewriter, and the Creed automatic 5-unit and Morse equipment. A glossary of telegraph terms and definitions is included.

PROBLEM OF REDUCING VULNERABILITY TO ATOMIC BOMBS. By A. J. Coale. Princeton University Press, Princeton, N. J., 1947. 116 pages, tables, 8 by $5^1/_4$ inches, cloth, $2. The problem as stated is analyzed under four main headings: reduction of vulnerability under an effective agreement on limitation of atomic weapons; reduction of vulnerability when atomic armament is unlimited; technical considerations of atomic weapons and possibilities for defense; the necessity for further research and analysis. The author does not seek to give final answers but rather, by analysis and synthesis, to show the exact nature of the questions awaiting answer, from both the physical and social points of view.

ROCKETS AND SPACE TRAVEL, THE FUTURE OF FLIGHT BEYOND THE STRATOSPHERE. By W. Ley. Viking Press, New York, 1947. 374 pages, illustrated, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $3.75. Beginning with the early concepts of space travel and conditions beyond the limits of the earth's atmosphere, the author proceeds to a discussion of the actual and practical development of the rocket as a means of motive power. The new edition presents an extensive account of the German experiments which lead to the *V-2* weapon. Considerable space is devoted to the technical and physiological problems connected with the take-off and controls for space flight. A technical data section and a bibliography are appended.

SCIENCE SINCE 1500. By H. T. Pledge. Philosophical Library, New York, 1947. 357 pages, illustrated, diagrams, charts, maps, tables, $9^3/_4$ by 6 inches, cloth, $5. Following an introductory discussion of scientific development prior to 1500, the succeeding centuries are considered successively, giving a cross-section of the parallel evolution of the several sciences. Together with the progressive discoveries and inventions and the epoch-making theories, some account is given of the men who contributed. This condensed recapitulation of the labors and achievements of science since the Renaissance is illustrated by charts, graphs, and maps demonstrating the continuity of the process. There are detailed subject and name indexes and a suggestive bibliographical note.

SIX-PLACE TABLES, WITH EXPLANATORY NOTES. By E. S. Allen. 7th edition. McGraw-Hill Book Company, New York and London, 1947. 232 pages, tables, $7^1/_4$ by $4^1/_4$ inches, cloth, $2.50. This standard reference book presents a selection of tables of squares, cubes, square and cube roots, fifth roots and powers, circumferences and areas of circles, common logarithms of numbers and of the trigonometric functions, natural trigonometric functions, natural logarithms, exponential and hyperbolic functions, and integrals. An introductory section explains briefly the theory of logarithms and the use of logarithmic and certain other tables.

STANDARD COSTS FOR MANUFACTURING. By S. B. Henrici. McGraw-Hill Book Company, New York and London, 1947. 289 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $3.50. This textbook presents a step-by-step description of the way in which standard-cost techniques are used for controlling manufacturing expense, and for simplifying cost-accounting procedures. It outlines the theory and practice of standard-cost accounting, covering the setting-up of accounts, developing the standard-cost system, setting standards for direct and indirect labor, materials, maintenance, fuel and power, and general overhead. It also shows how standard costs can be used to develop operating budgets and supervisory incentive plans. Emphasis is placed on specific procedures, illustrated by numerous examples of their use.

TABLES OF INTEGRALS AND OTHER MATHEMATICAL DATA. By H. B. Dwight. Revised edition. Macmillan Company, New York, 1947. 250 pages, diagrams, charts, tables, $8^1/_2$ by $5^1/_4$ inches, cloth, $2.50. Classified groups of derivatives and integrals are given for algebraic, trigonometric, exponential, logarithmic, hyperbolic, elliptic, and Bessel functions. Inverse trigonometric and hyperbolic functions also are covered, as are probability integrals, surface zonal harmonics, definite integrals, and differential equations. Tables of numerical values for various functions, logarithms, constants, and so forth, are appended, and there is a list of references.

GERMAN RESEARCH IN WORLD WAR II. By L. E. Simon. John Wiley and Sons, New York; Chapman and Hall, London, Ltd., 1947. 218 pages, illustrated, diagrams, tables, $9^1/_4$ by 6 inches, cloth, $4. The author, one of a group of scientists commissioned to visit Germany immediately after the surrender, presents an analysis of the organizations engaged in the German war research. In connection with this he surveys their important results in the fields of interior, exterior, and terminal ballistics, fire control, instruments and measurement techniques, and aerodynamics. Rockets, sonic devices, and other unusual types of weapons are described. An an appendix to the critical discussion of German research methods, the author concludes with a chapter of comments and criticisms applicable to research in general.

GUIDE TO THE LITERATURE OF MATHEMATICS AND PHYSICS INCLUDING RELATED WORKS ON ENGINEERING SCIENCE. By N. G. Parke III. McGraw-Hill Book Company, New York and London, 1947. 205 pages, tables, $9^1/_4$ by 6 inches, cloth, $6. A detailed bibliography is presented of world literature in the field of mathematics and physics, and related aspects of engineering science. Containing about 1,800 entries, the book provides scientists and research engineers with a valuable key to authoritative information, with strong industrial emphasis, on a wide range of subjects from algebra to atomic and nuclear physics. The main arrangement is an alphabetical subject classification, with orienting paragraphs and an author index. The early part of the book contains a helpful section on reading, reference, and library techniques.

TABLES OF THE MODIFIED HANKEL FUNCTIONS OF ORDER ONE-THIRD AND OF THEIR DERIVATIVES. By the staff of the computation laboratory. Annals of the Computation Laboratory of Harvard University, volume 2. Harvard University Press, Cambridge, Mass., 1945. 235 pages, diagrams, charts, tables, $10^3/_4$ by 8 inches, cloth, $10. The two main parts, Table 5 and Table 6, tabulate to eight decimal places the functions $h_1(z)$ and $h_1(z)$ for positive values of y from 0 to 6 at intervals of 0.1 Functional values for negative y may be obtained from the tables and certain indicated relationships. Introductory sections describe the modified Hankel functions and their properties and the method of computation of the functions. A selected bibliography is included.

UNIFIED CALCULUS. By E. S. Smith, M. Salkover, H. K. Justice. John Wiley and Sons, New York; Chapman and Hall, London, 1947. 507 pages, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $3.50. Planned as a first course in calculus, this text presents the fundamental ideas and applications of both differential and integral calculus in an alternating manner to demonstrate the unity of the subject. The correlation of calculus with physics and mechanics is emphasized by the early inclusion of problems dealing with important basic concepts in these fields. Differentials are given special consideration as the connecting link between differentiation and integration, and there is a chapter on differential equations.

WELDING SYMBOLS. By V. C. Gourley. Bruce Publi hing Company, Milwaukee, Wis., 1947. 115 pages, illustrated, diagrams, tables, $8^3/$ by $5^1/_2$ inches, cloth, $2.50. The general standards for the use of arc-, gas-, and resistance-welding symbols are explained in a simple, graphic way. Illustrations consist of two parts: the drawing specifies the weld in the same manner as an actual mechanical drawing or blueprint; the explanation interprets the drawing, showing pictorially the exact location and outline of the weld. The standards and symbols demonstrated are the ones recognized by the American Welding Society. An illustrated glossary is included.

CONTROL CHARTS IN FACTORY MANAGEMENT. By W. B. Rice. John Wiley and Sons, New York N. Y.; Chapman and Hall, London, England, 1947. 149 pages, diagrams, charts, tables, $9^1/_4$ by $5^3/_4$ inches, cloth, $2.50. The underlying theory of statistical control is first discussed, followed by practical information concerning its proper and effective use. Its basic functions in manufacturing plants are demonstrated. Intended particularly for the business or factory executive, the book should be of equal value to those who have the direct responsibility of such work.

ENGINEERING ECONOMICS AND PRACTICE, INCLUDING SOLUTIONS TO PROBLEMS IN PROFESSIONAL ENGINEER EXAMINATIONS, NEW YORK STATE. By M. J. Steinberg and W. Glendinning. Apply W. Glendinning, 5123 Bell Boulevard, Bayside, N. Y., 1947. 101 pages, diagrams, charts, tables, 11$^1/_2$ by 8$^1/_2$ inches, paper, $3. This book covers the basic principles of engineering economics and practice. The principles have been reduced to a formula basis with each of the terms clearly defined. Each chapter includes problems of a practical nature that illustrate the principles involved. Questions and solutions to the problems in engineering economics and practice from the New York state professional engineering examinations are an important supplement to the text material.

INTRODUCTION TO ATOMIC PHYSICS. By H. Semat. Revised and enlarged. Rinehart and Company, New York, N. Y., 1946. 412 pages, illustrated, diagrams, charts, tables, 9$^1/_4$ by 6 inches, cloth, $4.50. Presents important experimental data upon which are based the present ideas of the structure of the atom. Part I discusses the foundations of atomic physics, beginning with the elements of electricity and magnetism and continuing with detailed information on electromagnetic radiation, waves, and particles. Part II covers the extranuclear structure of the atom, while Part III deals with the nucleus itself and with nuclear energy. The major part of the revision is in Part III, with several new topics included, such as the discovery of new elements and the measurement of nuclear magnetic moments.

(AN) INTRODUCTION TO ENGINEERING PLASTICS. By D. W. Brown and W. T. Harris. Murray Hill Books, Inc., Technical Division, New York, N. Y., and Toronto, Ontario, Canada, 1947. 274 pages, illustrated, diagrams, charts, tables, 9$^1/_4$ by 6 inches, cloth, $4. A detailed account is given of the various plastics that have found commercial acceptance. Chapters are included on the engineering properties and the chemical and physical characteristics of plastics; applications and techniques in handling plastics; and a list of the types of plastics with trade names and manufacturers. The authors also have furnished plant and equipment data, design considerations, and commercial tolerances.

METHODS OF MATHEMATICAL PHYSICS. By H. Jeffreys and B. S. Jeffreys. University Press, Cambridge, England; Macmillan Company, New York, N. Y., 1946. 679 pages, diagrams, charts, tables, 10$^3/_4$ by 7 inches, cloth, $15. This book is intended to provide an account of those parts of pure mathematics that are most frequently needed in physics. Assuming a knowledge of calculus, successive chapters deal with scalars and vectors, tensors, matrices, multiple integrals, operational methods, complex variables, and various important theorems, equations, and functions with special chapters on wave motion and the conduction of heat.

RUSSIAN-ENGLISH TECHNICAL AND CHEMICAL DICTIONARY. By L. I. Callaham. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 794 pages, 8 by 5$^1/_2$ inches, fabrikoid, $10. Originally planned to cover the chemical and process industries, this dictionary has been expanded to give comprehensive coverage of mineralogy, metallurgy, mining and geology, general engineering, machinery and mechanics, electrical engineering, pharmacy, and botany. Frequently used terms are also included for aeronautics, agriculture, medicine, physics, mathematics, and other scientific fields. A general vocabulary is included in the same alphabet, together with a large number of prefixes and suffixes. American usage and spelling are followed rather than British in the English equivalents.

WESTINGHOUSE EDUCATIONAL FOUNDATION. George Westinghouse Centennial Forum (Science and Life in the World). Volume 1—Science and Civilization, the Future of Atomic Energy. 152 pages. Volume 2—Transportation, a Measurement of Civilization; Light, Life and Man. 236 pages. Volume 3—A Challenge to the World. 198 pages. McGraw-Hill Book Company, Whittlesey House Division, New York, N. Y., and London, England, 1946. Illustrated, diagrams, tables, 9$^1/_4$ by 6 inches, cloth, $7.50 per set, 3 volumes; $2.50 each volume. In this series of three volumes are reprinted some 30 addresses by leading scientists and educators. They constitute a survey of facts, views, and opinions related to the state of scientific activity in our present civilization and its possible effects upon the future development of that civilization. The achievements of the past are recognized, and the present benefits of technological advancement are demonstrated, but the complex problems of the near future are clearly stated with no solutions offered except indications as to the general sociological trends necessary to avert disaster.

INFRARED IN INDUSTRY. By W. J. Miskella. Miskella Infra-Red Company, Cleveland, Ohio, 1947. 64 pages, illustrated, diagrams, charts, tables, 7$^1/_2$ by 5 inches, paper, $2. The construction and operation of infrared equipment for industrial uses are explained in this trade pamphlet. Diagrams and charts are used to show structural details and furnish technical data.

PHOTOELECTRIC CELLS. By A. Sommer. Chemical Publishing Company, Brooklyn, N. Y., 1947. 104 pages, diagrams, charts, tables, 8$^3/_4$ by 5$^1/_4$ inches, cloth, $2.75. A brief survey of the principles of photoelectric emission is followed by a more detailed description of the manufacture and properties of photocathodes. In chapters V to VII an account is given of vacuum, gas-filled, and multiplier photocells and their relative advantages and limitations. The final chapter covers applications. Only cells of the emission type are dealt with in the book.

PAMPHLETS

Management Techniques for Increasing Labor Productivity (Production Series Number 163). This is a collection of three papers presented at the Spring production conference of the American Management Association, April 22–24, 1946, New York, N. Y. The topics include: Economic Considerations for Production Executives, Labor Productivity and Technological Advances, and What Is a Fair Day's Work. The pamphlet is available from the American Management Association, 330 West 42 Street, New York 18, N. Y. 51 pages, 75 cents.

Quality and Expense Control (Production Series Number 164). Three papers presented at the Spring Production Conference of the American Management Association, April 22–24, 1946, New York, N. Y. The topics include: Use of Pallets in Manufacturing, Reappraising the Quality Function, and Control Over Indirect Labor and Material Expenses. The pamphlet is available from the American Management Association, 330 West 42 Street, New York 18, N. Y. 24 pages, 50 cents.

Getting and Using Employees' Ideas (Production Series Number 165). Six papers that were presented at the Spring Production Conference of the American Management Association, April 22–24, 1946, New York, N. Y. Topics include: Why a Suggestion Plan?, Suggestion Plans—The Value to the Personnel Relations Program, Suggestion Statistics, Building a Suggestion Program, Training or Educating Imagineers, The Illinois Central Suggestion System, and a discussion. The pamphlet is available from the American Management Association, 330 West 42 Street, New York 18, N. Y. 31 pages, 50 cents.

The President's Conference on Fire Prevention. The program outlined in this report consolidates the recommendation of the six committees of the President's Conference on Fire Prevention. It is available from the Superintendent of Documents, United States Government Printing Office, Washington 25, D. C. 12 pages, five cents.

Recommended Practice for the Selection of Laminated Sheets for Use in Post Forming. Advisory Technical Committee, Laminated Products section of the National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y. (Publication Number 47-122), 25 cents.

Symposium on Testing of Parts and Assemblies, Technical Publication Number 72. A collection of seven papers presented at the 49th annual meeting of the American Society for Testing Materials in Buffalo, N. Y., June 26, 1946. This symposium was sponsored jointly by the American Society for Testing Materials and the Society for Experimental Stress Analyses. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.; 6 by 9 inches, 96 pages, $1.50.

Prevention of Deterioration Abstracts. These abstracts are being made available by the National Research Council of the National Academy of Sciences (Prevention of Deterioration Centre, Room 204), 2101 Constitution Avenue, Washington, D. C., on a yearly subscription basis. They are set up under the following headings: electric and electronic equipment; finished assemblies; fungicides; lacquers, paints, and varnishes; leathers; lubricants; metals; micro-organisms; optical instruments; packaging; papers; plastics; resins, rubbers, and waxes; storage; textiles; and wood. Items abstracted include general articles, patents, specifications, unpublished reports prepared by various Army, Navy, and other governmental groups, and unpublished British, Australian, and Canadian reports. There will be approximately 1,500 pages of the abstracts per year. They will come in loose-leaf form, and all abstracts classified under any one heading will be numbered consecutively. Price, which includes two binders and index guide, will be $37.50 per year. The fiscal year will be from July 1 to June 30, and for the year 1946 back issues will be supplied as these abstracts started in April 1946.

Standards for Electron Tube Basis, Caps and Terminals, NEMA Publication Number 500. A joint RMA–NEMA standard formulated by the Joint Electron Tube Engineering Council, 8$^1/_2$ by 11 inches, 19 pages, $1.50.

Standard for Dimensional Characteristics for Water-Cooled Transmitting Tubes, Publication Number 501. A joint RMA–NEMA standard formulated by the Joint Electron Tube Engineering Council, 8$^1/_2$ by 11 inches, 4 pages, 25 cents.